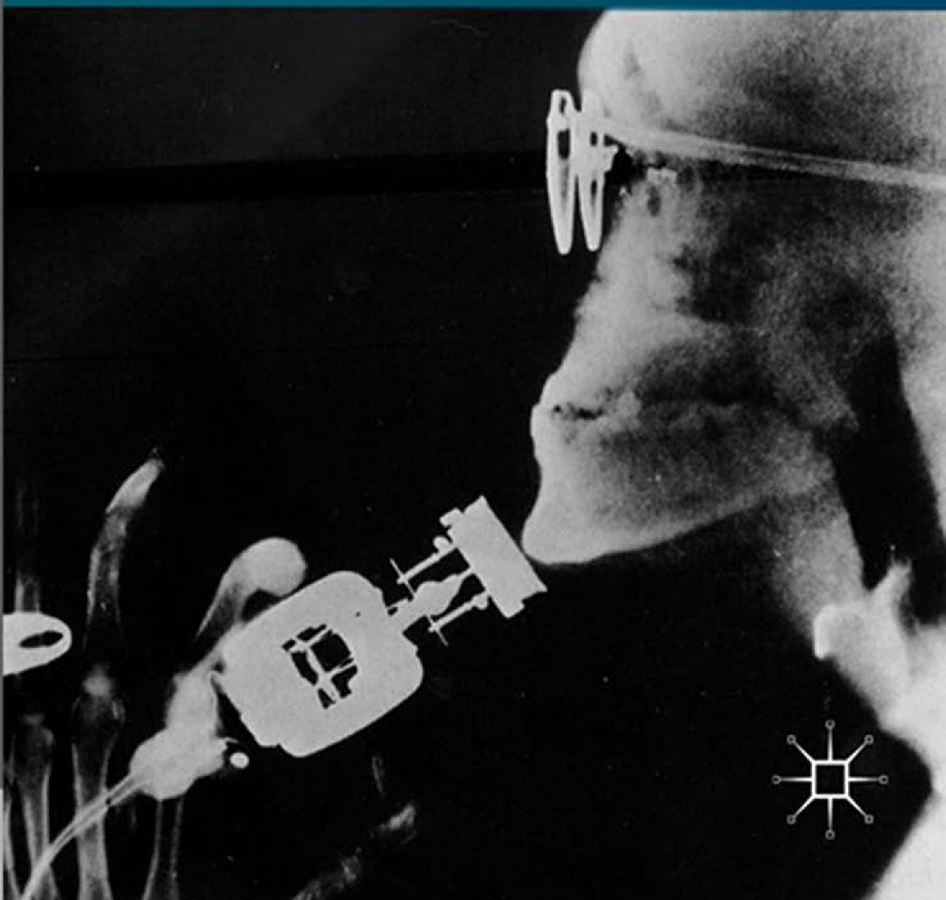
THE FIRST ATOMIC AGE

Scientists, Radiations, and the American Public, 1895-1945

MATTHEW LAVINE

PALGRAVE STUDIES IN THE HISTORY OF SCIENCE AND TECHNOLOGY



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Scientists, Radiations, and the American Public, 1895–1945

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Contents

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Figures

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Clichés are durable because they are useful. I find myself unable to avoid using the standard tropes of the acknowledgments page, so I will indulge in all of them at once. This book has many authors. It could not have happened without extraordinary effort on the part of people far exceeding their professional or educational obligations toward me. And, regrettably, I cannot mention them all here.

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Archival Sources

ACR	Archives of the American College of Radiology
AMA	Archives of the American Medical Association, Historical Health Fraud and Alternative Medicine Collection
Bakken	The Bakken Museum of Electricity and Life
Columbia	Columbia University Rare Book and Manuscript Library, William Brown Meloney Collection
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Martland	Harrison Martland Papers, University of Medicine and Dentistry of New Jersey Library Special Collections
NLM	United States National Library of Medicine, Historical Collections
ORAU	Oak Ridge Associated Universities, Health Physics Historical Instrumentation Collection
Paskow	Paskow Science Fiction Collection, Temple University Libraries
SIA	Smithsonian Institution Archives
Williamson	Jack Williamson Science Fiction Library, Eastern New Mexico University-Portales

Chapter 1

Introduction

In March 2011, three nuclear reactors melted down at the Fukushima I Nuclear Power Plant when their safety systems were overwhelmed by the effects of a tsunami. Radioactive substances were released into the atmosphere and the Pacific Ocean. A number of workers and emergency responders received more exposure to radiation than the legally permissible lifetime limit. The historic poignancy of Japan once again suffering the effects of an uncontrolled nuclear chain reaction was not lost on commentators. Sam Biddle, writing for the pop technology website Gizmodo, reported that the cesium-137 released by the reactors was the radiological equivalent of 168 Hiroshimas. Lest he be misunderstood, Biddle immediately acknowledged the difference between an exploding bomb and a melting reactor. Whereas most of the victims of Hiroshima had been killed by the instantaneous heat or pressure, "Fukushima's release is slower—more insidious. A deadly leak that's seeped into the earth, water, food, and urine of Japan."[1] Others quickly pointed out that the danger was not limited to Japan. Beneath a photo composition of a tin can bearing the nuclear trefoil warning symbol, Fox News's health correspondent Chris Kilham fulminated that three months after the incident, American "milk, fruits and vegetables show trace amounts of radioactive isotopes from the Fukushima Daichi power plants, and the media appears to be paying scant attention, if any attention at all."[2] Kilham was correct about the radiation but mistaken about the attention it was getting. For months after the incident, the American media landscape was saturated with risk assessments of nuclear energy, claims and counterclaims about the relative dangers of radioisotopes, and what (if anything) individual Americans might do to protect themselves.

Several years earlier, the journalist Ron Rosenbaum had also reflected on the victims of Hiroshima. From the perspective of what he called the Second Nuclear Age (the first, in his reckoning, having spanned the period from the bombing of Hiroshima through the end of the Cold War), Rosenbaum mused on the special status accorded to the city's dead. "What made the bright line between nuclear mass slaughter and non-nuclear mass slaughter so bright? Was it the radiation, in its invisible insidiousness and—more importantly—in the longevity of its deadliness?" He concluded that after 63 years of rebuilding, the city of Hiroshima might once again have become "too normal" for anyone's good, with the physical and moral horrors that it had once represented sanitized through an overabundance of museums. "We checked in to the First Nuclear Age that day in 1945, and yes, sometimes we check out, in the sense of repressed memory, willed or unconscious denial, cultural amnesia. . . . That all-too-brief 'holiday from history,' some called it."[3]

Notwithstanding Rosenbaum's experiences in the modern Hiroshima, radiation's "invisible insidiousness" has been the subject of fresh anxiety in recent years. The introduction of backscatter x-ray machines at airline security checkpoints provoked concerns about their effect on health, and because the images they produced were sometimes immodestly explicit about the shape of their subjects' bodies.[4] Video clips showing cell phones cooking eggs or popping popcorn have circulated on the Internet, provoking amusement or horror depending on whether or not the viewer subscribes to the belief that cell phones emit dangerous radiations. One of the videos was part of a viral advertising campaign for a manufacturer of wireless headsets.[5] The Radiological Society of North America, a professional organization representing the medical professionals responsible for administering much of the typical American's annual dose of radiation, cited public alarm and negative press coverage of the cumulative effects of diagnostic x-rays and CT scans when it announced in 2010 its campaign to reduce unnecessary imaging.[6] These concerns can be put on a long list of contemporary nuclear anxieties that includes environmental radon, radioactive "dirty bombs," and nuclear waste storage.

The collective public response to all of these radiation stimuli has been fairly predictable. We know, from repeated experience, how people in our present "Nuclear Age" tend to respond to such things. Fukushima was unexpected, but not the nature of the discourse that followed it, because it had been rehearsed after Chernobyl, Three Mile Island, and dozens of lesser nuclear crises. Some version of Rosenbaum's meditation on Hiroshima and cultural memory appears every so often, usually around the August 6 anniversary of the bombing. The historical literature is so deep, in fact, that it defies easy synthesis or even summary. Critical work exists on, among other subjects, the iconography of the mushroom cloud, the gender politics of nuclear power in the 1980s, and the national identity constructed for nuclear technologies by French engineers.[7] Yet these studies have focused on the post-Hiroshima world, to the near exclusion of anything that happened before the Trinity test. This gap in the scholarly reckoning has implications not only for our understanding of the postwar confrontation with those energies, but also for the relationship between the laity and the scientific and medical establishments of the early twentieth century.

Rosenbaum began his chronology of the "nuclear ages" in 1945 for reasons that are clear enough, but if a nuclear age is characterized by an awareness of the destructive potential of uranium and the fear of radiation, then his chronology itself reflects a different sort of "cultural amnesia." In fact, starting with the discovery of x-rays in 1895 and radioactivity in 1896, Americans of all sorts took part in discussion about, debate on, and displays of the energies that arose from scientists' inquiries into the atom. Far from a "holiday," this was a period in which the laity took an active interest in the new phenomena. Nevertheless, there are many questions about it that remain largely unanswered. How much information did the public receive about x-rays, radioactivity, gamma rays, cosmic rays, and other new emanations from the atom? Where did it come from, and what interests did those sources have in disseminating it? What events or agents had the power to shape the evolving ray-rhetoric? Why was there such a broad range of opinions and knowledge about the phenomena?

Nuclear Culture

Kirk Willis coined the term "nuclear culture" in an essay demonstrating that it was alive and well in Britain long before Hiroshima and Nagasaki—that "the knowledge, imagery, and artifacts of applied nuclear physics" had become a part of many Britons' mental furnishings by virtue of the many popular books, movies, science fiction magazines, newspaper articles, demonstrations, and so forth that injected those topics into the public discourse.[8] The concept makes intuitive sense: the "atomic age," like the space age or the jazz age, is more than a convenient shorthand for cultural historians.[9] These informal periodizations suggest the continuous influence of an idea at work across a broad swath of a culture. Americans' understandings of radiation and radioactivity were complicated enough to persist beyond any momentary experiential or rhetorical contact with them.

They were, in other words, one of the lenses through which Americans interpreted the broader culture of which they were a part. A patient of 1905, sitting for her first x-ray examination, would most likely have a fairly good idea of what the actual machine could do, what sorts of ailments it could diagnose, and what its images would look like. But she would also have a decade's worth of experiences of "x-ray" as a rhetorical and metaphorical entity: within that time the word had come to connote *omniscient, penetrating, exposure* (psychological and physical), *modern, mystical, vital, inscrutable,* and *scientific*. Radium might be, for such a person, at various times an intellectual curiosity, a sign of the times, a symbol of wealth, a consumer novelty, and a medicine of last resort.

Notwithstanding Willis's example, most studies of nuclear culture have dealt with the postwar period.[10] Yet many of the individual anecdotes and episodes of early American nuclear culture have proven attractive to historians. Often (and appropriately) these works draw much of their narrative impact from what is now a rather striking disconnect between the nuclear fears of today and the levels of irradiation that Americans once experienced, or the casualness with which some actors allowed themselves to be exposed. It is all but impossible not to marvel at what looks like naïveté in the story of the millionaire who drank radium tonic until his jaw fell off, or the sangfroid of Elihu Thomson when he decided to sacrifice his left little finger in order to better establish the upper limit for x-ray tissue damage.

Yet, for the most part, the emphasis in each of these carefully focused studies has been on something other than the cultural impact of the new energies. For instance, in their admirably thorough article on shoe store fluoroscopes, Charles Duffin and Jacalyn Hayter explain the "rise and fall" of such machines by way of exploring the concept of scientific motherhood and the growing commercial appeal of science in the twentieth century.[11] Rebecca Herzig's excellent exploration of beauty parlor x-ray depilation is really a story about the "larger problems of race, sex, and science in the interwar period."[12] Claudia Clark's consideration of the storied "radium girls," whose long and public martyrdom to both the element itself and to the callous indifference of their employers was a crucial turning point in American nuclear culture, is first and foremost a work about industrial health reform.[13]

In these studies, what the general public understood about radiation at any given moment is referred to only in general terms, and varies greatly. With the exception of Spencer Weart's *Nuclear Fear: A History of Images* (1988), which explores the symbolism of nuclear energies in an attempt to elucidate their collective psychological underpinnings, there is no baseline study for the prewar period against which the invariable reference to the "public sentiment" can be calibrated. Almost no work has been done that accounts for the experience of those energies across the various sites of encounters that nonscientists had with them: the clinic, the studio, the beauty parlor, the sideshow, the shoe store, and so forth. Likewise, while the popular presentation of x-rays has been considered in specific instances—most radiologist-authored histories of the technological development contain a few pages on the extraordinary attention they received in the newspapers during 1896, for instance—little consideration has been given to how that attention varies across different media, or in different stages of the rays' public life.[14]

* * *

Like everyone else I am aware of who has studied the early years of radiation in the public domain, I have had a certain experience many times over. I am introduced to a person of a certain age—born, say, before 1955—who inquires after my work. Upon being told that it has to do with radiation and how people interacted with it, he or she immediately urges me to look into an extraordinary curiosity they encountered as a child: the shoe store fluoroscopy machine.[15] I have also had versions of this conversation in which my new acquaintance tells me about prospecting for radioactive glass souvenirs at bomb-testing sites, or describes the x-ray machine that gathered dust in a beauty parlor they went to as a child, or relates the story of how a doctor used massive doses of x-rays to treat their eczema or other minor ailment. Of course, these sorts of encounters were in fact quite common, but before I get the chance to launch into the ten-second summary of my work, my partners in these conversations move swiftly to the moral of their stories: *it's amazing the risks we took when we didn't know any better.*

To some extent, the post hoc astonishment we presently feel at the radiation exposures of yesteryear is an understandable consequence of the fact that medical professionals, who have now all but cornered the market on the artificial irradiation of the human body, have learned to do much more with much less. The oft-repeated factoid that a transatlantic flight exposes passengers to some fraction of the radiation dose of a routine chest x-ray goes out of date fairly quickly, thanks to incremental improvements in the technology that require less and less ionizing radiation. Even the most heroic therapeutic irradiation today is positively homeopathic in comparison to the initial standard of care, which was to point the emitter at the problem and leave it on until the skin burned.

But (as I am at pains to tell my new friends), it is simply not the case that we have only recently become "knowledgeable" with respect to these energies. It only seems that way because the points of contact between radiation and our bodies and minds are far fewer and have become far more constrained. In the glare of atomic fireballs, some sense of the extent to which these energies once pervaded the experiences of nonscientist Americans has been lost. Consider, for example, John Bradley's edited volume *Learning to Glow: A Nuclear Reader*. In its introduction, titled "Invisibility," Bradley enumerates the iconography of the Nuclear Age: the rubble of Hiroshima, the Doomsday clock, Bert the Turtle, and Slim Pickens perched atop an atom bomb. For Bradley, though, the most compelling images are those of "everyday people," which leads him into the story of his visit to Ottawa, Illinois, the site of a factory that produced radium-luminous paints, and which was, like several other such plants, the subject of much-publicized lawsuits in the 1930s, filed by employees who had contracted radiation-related illnesses. Standing on the site of the now-demolished factory, Bradley sees the affair as "largely forgotten, another missing chapter in our nation's nuclear history." His evidence for "forgetfulness" is compelling: the still-radioactive site had been used in intervening years as a farmer's market.[16] But only one of the 24 essays that follows deals with any prewar encounters with radiation—Catherine Quigg's recounting of her interviews with surviving workers from the Ottawa plant, and that mostly as a preface to her treatment of *tritium* dial painters in the 1970s.[17]

This elision is problematic for several reasons beyond the fact that it simply fails to reflect the reality in which Americans conjured with the rhetoric and reality of fantastical new energies on a daily basis. For one, as I have already suggested, both the scientific and medical establishments looked different to Americans when viewed by the light of the x-ray tube or radium paint. Their light, as the public quickly came to understand, flickered in unpredictable ways. "The news of scientific effort is overshadowing all other news," rhapsodized the *New York Times* in 1913. "More significant than a change of ministry in France or the issue of a Balkan war is the announcement a Soddy or a Ramsay may make tomorrow about the loosening of forces in groups of atoms. . . . They are the mighty men of these days. They have done much, and they promise more."[18] The occasion for this cheerful acknowledgment of scientists' newfound social currency was the apparently successful treatment by radium of a New

Jersey congressman suffering from cancer. When he died anyway a few months later, the *Times* put this in the headline of his obituary: "Cancer Victim Whom Radium Could Not Save Had Faith in It to the End." Bremner's "absolute faith" in his doctors' modern armamentarium persisted until the moment he lapsed into his final coma, it reported, and he had spent much of his last days working on a bill that he hoped would make radium treatment more widely available.[19] But his decline had led the *Times* to editorially denounce the state of affairs that had led Bremner to put such faith in radium in the first place. Palpably angry with the physicians who had asked journalists to exercise restraint in their treatment of radium's healing potential, for fear that it would create false hope and delay treatment, the *Times* editorialist fumed that doctors "could hardly hope for a more thorough enlightening of the public on this point than it receives through the *spectacular failure* of the much-heralded remedy in the case of Congressman Robert Bremner."[20] This particular hairpin turn in one newspaper's pronouncements on radium did not foreshadow any sort of sea change in how radium was regarded by its readers. Diametrically opposed sentiments about radiation coexisted in the public discourse for decades after Bremner's death. But it does illustrate how closely the prestige of science and medicine was tied to these energies.

Another problem with an overly simplified received history of early American nuclear culture is that it neglects a broad network of actors who helped shaped the public discourse. X-rays and radium were utterly commercialized, in every possible way: not only were the energies themselves bought and sold, but so was access to the discussion about them in the form of books, lectures, and news reports. The crowds of entrepreneurs behind everything from ersatz cure-all radium ointments to x-ray portraiture studios figured heavily in the reception that those energies had.

Historians of science no longer assume that science popularization is a simple process of diffusion or translation from active knowledge-makers to passive lay audiences, but the enthusiastic appropriation and reinterpretation of radiation and radioactivity by nonscientist Americans is a prime example of just how much agency the popularizer's audience can have. Unheard of demand for news of the new rays surprised editors, enriched lecture-demonstrators, and launched new businesses. Ray-talk also created new channels of communication between professionals and the general public. Popularizing scientists like Frederick Soddy and William Hammer saw their career paths altered by radium fame, while orthodox medicine was able to use the public's interest to consolidate its professional standing twice—initially by encouraging belief in the imminence of a radiation panacea, and then again decades later by asserting that only scientific medicine could neutralize the threat that those same energies posed. All the while, countless commercial actors, makers and buyers alike, were coauthoring a narrative about how, when, and under what circumstances these energies could be brought to market.

Finally, a history of nuclear culture that is coeval with the history of the Cold War suffers from the implicit assumption that both were born in the same flash of light: that the rich emotional spectra on display in Americans' reactions to atomic espionage, nuclear power, and basement radon were entirely the product of the moments in which they first arose. Otherwise excellent treatments of radiation in postwar American culture have faltered on the subject of where their subjects got their ideas about nuclear energy, weapons, or medicine in the first place, offering either no explanation or one in which all causal chains lead back to banner headlines about atom bombs. Yet Americans did not enter the next atomic age unprepared. The incomparably dramatic timing with which nuclear weapons made their debut took the public by surprise, but not the weapons themselves. Because it had been a staple of speculative fiction for 40 years, the atom bomb was as well-understood a concept as Luke Skywalker's light saber might be if it were suddenly commercially available today. Radioactive fallout—little explored by science fiction, and indeed greatly underestimated by Manhattan Project scientists themselves—was frightening not merely because of news that trickled back from occupied Japan, but also because the concept of insidious poisoning by undetectable radioisotopes had already been rehearsed in the public sphere for decades. Nuclear tourists who set out with picnic lunches to watch mushroom clouds rise up from bomb test sites were traveling the same roads that had led health tourists to the radium springs: the mountains and deserts of the West had been glowing a faint radioactive green on Americans' mental map for decades already.

* * *

Daniel Thurs has argued that popular understandings of scientific phenomena, necessarily dynamic things, can best be understood as "a reservoir of 'tools' with which people can interpret texts and construct meanings," made up of the "words, phrases, anecdotes, images and ideas that are used to construct science."[21] This method has the advantage of permitting a holistic view of how an idea or technology was read into the collective understanding without silencing its minority reports. It is particularly valuable for approaching the cultural history of radiation, a subject in which the minority opinions at any moment were vocal and diverse: the tools they represented were occasionally taken up to dismantle the consensus. The sources I have worked with in constructing the chapters that follow have forced me to acknowledge the truth in what may already be a truism of cultural histories of science: that the "public," by whatever name, is neither uniform, nor passive, nor ever so ignorant of the substance and significance of the works of the scientific establishment as might be assumed. No generic attitude about radiation exists that can be straightforwardly summarized, because there were so many ways in which that attitude could be formed, and several of them—the first newspaper article read, the attitude of a high school science teacher, the first time an x-ray machine was brought near a broken bone—could be both potentially deeply affective and highly idiosyncratic.

Nevertheless, I am also convinced that meaningful generalizations can be made about those experiences, and that where first-hand testimony is unavailable, we can come very close to an understanding of the prevailing sentiments by looking at the interplay between that general public and specific interested parties—doctors, manufacturers, writers, salesmen, inventors, resort owners, government officials, mining companies, scientists, and others—on the subject of the rays. It may not be possible to know now how Tho-Radia face powder compared to its mundane competitors in the 1930s, but we can gain some insight about what buyers might have expected from its advertisements' explication of its unique thorium-radium blend, or the fact that it was formulated by one Dr. Alfred Curie (no relation), or the warm glow in which it basks the face of the model painted on its posters.[22] Enough testimonials about what it was like to be x-rayed in the early 1900s survive to give us a general sense of the impressions left by that experience, but the picture is greatly enhanced by knowing what those early patients would have read in the newspapers, or books, or heard from neighbors who had attended an exhibition.

Class and racial boundaries affected participation in nuclear culture; gender and geography tended not to. Science popularization, whether in the form of newspaper columns, mechanics' libraries, or public lectures, tended to connect elite scientists with elite lay audiences, and this was as true with respect to these new energies as it was for any other subject. Yet few Americans were entirely innocent of nuclear culture in the first half century after the discovery of x-rays. Both medical x-rays and consumer radium products were fairly democratic in their dissemination. Naturally occurring radon, sought out by health tourists in the nation's western hot springs, meant that the populations of these rural areas were unusually active participants in shaping the understanding of radioactivity. Even in rural areas where electrification came late, physicians made generator-powered x-ray machines part of their practice more or less in parallel with the rest of the country. By the 1910s, to the extent that Americans could command the attention of an orthodox medical doctor or be admitted to a hospital, they could and did encounter medical irradiation. This is not, of course, the same thing as saying that this kind of access was universal. Poverty and racial marginalization could and did keep many Americans from both rhetorical and physical encounters with the new energies.

Women and men participated in nuclear culture to a similar extent, albeit through different channels. Much early medical experimentation with x-rays and radium focused on gynecological disorders, or cancers of the female reproductive system. To some extent, this had to do with the fact that, by virtue of the vaginal canal, more internal volume of women's bodies could be directly exposed to radiation. It may also be a reflection of the persistent sexual undertone that attended discussion of x-rays: "exposure" suggests voyeurism. Nervous jokes about electrical peeping toms and lead-lined undergarments were a commonplace of nuclear culture, and ubiquitous in its early days. (Radium, too, was sexualized: it was broadly understood to be somehow "alive," and that vitality quickly became equated with sexual potency via patent medicines aimed at both sexes.) Men more commonly consumed books on popular science and science fiction, and were, of course, more likely to be professionally situated to administer them. But the highly commercialized nature of the discourse meant that women were a part of it: not just as medical consumers, or as the target of x-ray depilation or ersatz "radium" cosmetics, but as an audience that needed to be propitiated before any sort of radiant health device might be brought into the home.

The Discovery of X-Rays and Radioactivity

A brief primer on the discovery and ramifications of these energies will help orient what follows. In early November 1895, Wilhelm Conrad Roentgen, professor of physics at Würzburg, was experimenting in his laboratory with electrical discharges through evacuated glass vessels, a subject that had been of considerable and consistent interest to physicists for decades, perhaps not least because of the attractive and novel colored light that shimmied along the interior of the tubes. While performing an experiment on a tube designed with an aluminum "window" to permit the egress of cathode rays (latterly understood as electrons) from the tube, he noticed a glow from a nearby piece of cardboard that had been painted with the fluorescing substance barium platinocyanide. Cathode rays can cause that effect, but the tube he was using was covered in black cardboard, which would have blocked cathode rays. Recognizing the anomaly, Roentgen repeated the experiment on November 8, using a different tube, and again observed the screen to fluoresce, and that whatever was emanating from the shielded tube could be blocked from the screen only by dense materials—metal, or the bones of his hand. Following several weeks of intense experimentation to determine the physical properties of the *x-strahlen* (so named for their unknown nature, by analogy to an unknown mathematical quantity *x*), during which the iconic Hand mit Ringen image of his wife's left hand was taken, Roentgen sketched his tentative conclusions about the rays in a communication to the Würzburg Physical Medical Society titled "Eine Neue Art von Strahlen" (On a new kind of rays) (See Figure 1.1). This was received on December 28.

X-rays belonged to popular audiences from the start. Attentive readers of the *New York Sun* would have learned on January 6, 1896 of a "photographic discovery which seems almost uncanny," as the headline had it.[23] The first brief hint at x-rays' unique properties therefore reached the general public before it reached specialized audiences: the *Sun* carried news of x-rays two days before any technical journal did.[24] By February, the bones of Frau Roentgen's hand had been reproduced in hundreds of newspapers and magazines. The excitement and consternation caused by the x-rays within the physics community was considerable: no extant physical model predicted such a phenomenon, and none provided a straightforward explanation. In February 1896, acting on the belief that Roentgen rays were related to the fluorescence that appeared inside the tubes that generated them, Henri Becquerel undertook a series of experiments to more clearly establish the relationship between the two phenomena. Salts of uranium were highly fluorescent; therefore, Becquerel exposed a sample to sunlight and observed that it exposed a photographic plate that had been covered in black paper. This would have confirmed his hypothesis, but uranium salts that had *not* been exposed to visible light, and therefore did not fluoresce, also exposed covered plates. Uranium, Becquerel concluded, was emitting something akin to an x-ray, but not because of its fluorescent properties.

Figure 1.1 Roentgen's "Hand Mit Ringen." The bones of Frau Roentgen's hand, in an image that quickly found its way into the popular press.

Becquerel's rays joined a host of other subtle emanations, real and imagined, competing for the attention of physicists at the close of the nineteenth century. Thorium was shortly shown by Marie Curie to possess the same property. Only after Pierre and Marie Curie observed that uranium ore gave off much more of the energy Becquerel had observed than its actual uranium content could account for—a discovery that led to their isolation in 1898 of the much more highly radioactive elements polonium and radium—was the study of radioactivity put on a firm enough footing to attract much broader interest. Among those interested were Ernest Rutherford and Frederick Soddy, who came together at McGill University in Montreal. Rutherford characterized the particulate emissions of a radioactive atom, and Soddy helped him develop a theory of atomic transmutation. On realizing that radioactivity was, in fact, the instantaneous change of one element into another, Rutherford famously shouted, "For Mike's sake, Soddy! Don't call it transmutation. They'll have our heads off as alchemists!" If Rutherford really felt any apprehension, it was that his scientific colleagues would look askance at such an extraordinary claim. The public, however, uncharacteristically attentive to these developments as they were reported in newspapers, was thrilled by the possibility of such "alchemy."

Meanwhile, Roentgen had been awarded the first Nobel Prize for physics in 1901. In all probability he lent the fledgling prize as much credibility as he took away from it, given the mania that had attended the discovery of x-rays, and their enduring power to startle and delight. By 1903, when the Curies and Becquerel shared the same prize for their discovery and characterization of radioactivity, the attention that attended the award (and the publicity that was attaching to Soddy and Rutherford's transmutation theory) was enough kindling to set afire a public craze about radioactivity in general and radium specifically that took four years to dwindle even slightly. The story of the Curies' isolation of precious radium (and polonium, actually found first, but usually written out of the popular retellings) from cartloads of otherwise worthless Bohemian ore congealed immediately into a widely told parable about dogged and clear-headed scientists pursuing the glimmer of knowledge, no matter what the obstacles. Like Roentgen and his stateside elaborators before them, the Curies became famous, as did Becquerel, Soddy, Rutherford, and quite a few people with more tenuous credentials who were willing to pontificate for a reporter or a lecture hall audience on the marvelous new substance radium.

By 1910, a consensus was only just beginning to emerge among physical scientists about how the pieces all fit together. Roentgen rays and the alpha-beta-gamma troika of radioactive emissions were not the only recently discovered anomalies that needed to be hammered back into place; there were also canal rays, N rays, "black light," electrons, helium, and dozens of other equally unruly phenomena to account for.[25] The atomic nature of matter itself would not even achieve an overwhelming adherence among working physicists for several decades. Nevertheless, a few facts that would form the baseline of popularizations for the next 35 years were generally agreed upon: alpha particles were charged helium nuclei; beta particles were highly energetic electrons, and gamma rays were electromagnetic waves of a somewhat higher frequency than x-rays, which were in turn analogous to (if rarely presented in the same way as) visible light. Radioactivity was established as a natural property of several types of matter—or possibly all matter, but only detectably so in a few rare metals. And, most importantly in terms of provoking interest from nonscientists, all of these new energies could act upon the body in dramatic and potentially drastic ways.

Ionizing radiation, including x-rays and gamma rays, and the particulate alpha and beta emissions of radioactivity, have a host of physiological effects that were recognized almost immediately by their first scientific elaborators. Although the mechanism of action is different for each type of radiation, the effects are collectively similar. Mild or moderate exposure to an external source of radiation causes localized swelling, erythema (redness), and hair loss. Greater exposure can cause tissue necrosis, sterility (if applied to gonadal cells), and malignancies. Because diseased or cancerous tissue is generally less hardy than healthy tissue, a dose sufficient to "burn" away the former produces relatively minor effects in the latter. The body's response to irradiation includes temporarily increased production of red blood cells, which can cause a deceptive feeling of increased healthiness for a short time before more serious symptoms manifest.

A new medical discipline arose at the turn of the century to better establish the nature of that physiological reaction. Early radiological societies sheltered engineers, and physicists and photographers who had hung out shingles to capitalize on the demand for diagnostic images, but most of their members were scientifically minded physicians who gravitated toward x-ray machines as much for their ostentatiously technological nature as for their immediate clinical application. Collectively, radiologists effected substantial changes in x-ray emitter technology, invented imaging and therapeutic techniques through trial and error, established a series of dosages and physiological responses, and (too late for many of the charter members of radiological societies) developed the first protections against chronic radiation exposure.

The extent to which the body is affected by x-irradiation depends on the intensity and "hardness" of the rays used and the duration of the exposure. "Hard" x-rays are of higher frequency than "soft" ones; gamma rays are typically of still shorter frequency than hard x-rays. Both penetrate more deeply into a body than does particulate radiation: beta particles penetrate more deeply than the much larger alpha particles, which are mostly blocked by the skin. As a result, radium (an alpha emitter) must be inserted into the body in sealed capsules to treat internal cancers. Likewise, it poses a greater risk as a carcinogen when ingested or inhaled—it displaces chemically similar calcium in bones—than when exposure occurs externally, both because ingestion prolongs the length of exposure, and because the energies are not absorbed by the skin, but penetrate directly to living tissue. Infertility via somatic cell death and malignancies caused by errors introduced into DNA are cumulative; other effects of irradiation are acute. Although the biochemical mechanisms of radiation's effects were not precisely understood until much later, it was widely known to physicists, clinicians, and laypersons alike even by the end of the nineteenth century that these new energies had the power to wither, restore, and alter human flesh.

Between 1910 and 1945, other kinds of radiation were recognized: neutron radiation, cosmic rays, and some of the more exotic forms of radioactive decay. The four discrete decay chains themselves were eventually worked out to a high degree of precision. Neutrons, positrons, and neutrinos were added to the list of elementary particles. Quantum mechanics provided mathematical rigor for the nuclear model that coalesced out of the chaos sown by Roentgen and Becquerel's discoveries. Research into radiation's physiological effect had begun before 1896 drew to a close, and has continued in earnest since, but most changes in application methods or dosages happened by virtue of experience gained from bedside: radiation sickness was difficult to treat except by treating the symptoms, and the mechanism of x-ray-induced mutations had to wait for a molecular-level understanding of genetics that would not come until the function of DNA was deduced.

Exploration of radioactivity directly informed work on atomic structure, and was essential to the development of quantum theory, which in turn helped establish a mechanism for electromagnetic radiation, including x-rays. Much of this work was far less well communicated to the public than the initial discoveries had been (and far more opaque when it was). The same held true for research into the clinical applications of x-rays and radium: radiology as practiced evolved rapidly in its first few decades, but many of the most significant changes were not apparent to patients. A few later developments in radiation did further pique the public's interest. In 1926, Herman Muller demonstrated that x-rays could induce heritable mutations; this, along with several other contemporary discoveries related to x-rays' biological effect, attracted the attention of a nation that was already intrigued by hereditary matters. Cosmic rays, first announced by Robert Millikan in 1925 (and immediately characterized by reporters as super-x-rays), remained a staple of science journalism for decades, not least because of Millikan's penchant for self-promotion. Proton and neutron bombardment of the nucleus ("atom-smashing," as the papers usually had it), undertaken by several prominent researchers beginning in 1932, revived long-simmering expectations that the natural transmutation of radioactive substances might lead to at-will transmutations by scientific alchemists.

For the physics community of the early twentieth century, these radiations were a set of experimental results in search of a theory. But for nonscientists, the word “radiation” was coming to signify a collection of bizarre new phenomena that were both fascinating and terrifying. By 1900 the American public was accustomed to the idea that most scientific knowledge had passed permanently beyond the grasp of the layman. The question of precisely which atomic structure must give rise to certain flashes on a phosphorescent screen was one about which most laypersons were content to remain agnostic. Yet they were far from agnostic about the x-ray, and a general ignorance of thermodynamics did not blunt their interest in the energies that, as they were now told, lurked inside the atom.

Synopsis

This book is intended to serve two purposes. It provides a thorough survey of early American nuclear culture, following the many meandering channels of the public’s understanding of these new radiant energies. The intensity and longevity of that interest, and the diverse ways it manifested itself among different segments of the population, is remarkable: never before had the work of scientists so gripped the attention of the American public, and never before had that interest found so many different means of expression. X-rays changed what it meant to go to the doctor; they also changed the language, the visual culture, and the legal system. The expectations projected on to the blank slate of radioactivity brought whole industries into existence before it had accomplished much more than parlor tricks with phosphorescent paint. In textbooks and comic books, at world fairs and state fairs, in patent medicines and research hospitals, and from the ivory tower to the remotest reaches of the Rockies, they became a symbol of a new sort of world for Americans.

Accordingly, this is also an exploration of how those energies shaped Americans’ understanding of the newly scientific world they lived in. Almost instantly, radiation and radioactivity were not merely subjects of scientific scrutiny; they were icons of scientific modernity. Astonishing in their novelty, exhilarating in their promise, and potentially troubling for their destructive power, nuclear emanations were an excellent and persistent metaphor for modern science in America at the turn of the twentieth century—and were relentlessly invoked as such. Many physicians concluded that their practice must, in order to be taken seriously, acquire an x-ray machine by whatever means necessary. The celebrity scientists of a whole generation were those who concerned themselves with novel images (Roentgen and Edison), novel substances (the Curies and Becquerel)—and novel energies (Soddy, Fermi, and—notwithstanding the reality of the situation—Einstein). Radiant energy even made old things new again, in the public discourse: x-ray exposures were the "new photography," and dissolved radon put a scientific spin on health spas' ancient claims to therapeutic value.

Notwithstanding all the usual caveats that must attend blanket statements about public perceptions on complicated subjects, early nuclear culture is remarkable for its complexity and internal self-contradiction. At no point does the murky medium of public opinion crystallize into anything like a consensus; sentiment about the new rays was a matter of debate at every turn. However, the nature of that debate is rather more tractable. There were three distinct phases to how the American public treated the new energies: first as an object of fascination and obsession, then as a commodity, and finally as a known (and largely disdained) quantity.

Chapter 2 discusses the extraordinary public mania for these new rays. This was the result of an equal partnership between an opportunistic news media and its fascinated readership: never before had an American audience shown such intense and sustained enthusiasm for the products of the physics laboratory. Perhaps surprisingly, the reaction had little to do with the immediate practical applications of x-rays or radium. The "new photography" was genuinely eerie, and quickly became a object of desire for physicians who wished to establish themselves as acolytes of the new scientific medicine. Its *proven* usefulness in those first several years, though, was in the setting of fractures and the removal of buckshot and needles, and a few interesting but recondite applications like the identification of gemstones. Radium was even less immediately useful during its first years in the spotlight, and was in any event (correctly) understood to be so rare in its refined form as to be unobtainable in any quantity. The *imagined* applications of the new energies were, by contrast, almost without limit. These contributed rather more to what Carolyn Thomas de la Peña has called "radiomania" at the turn of the century: it is easier to say what powers were *not* attributed to x-ray machines or radium ore, pending some final breakthrough that would allow their potential to be used at will.[26]

Yet it seems that the real source of the public's excitement was their manifest iconoclasm: they were, as a classic bit of x-ray doggerel put it, *naughty*. The mixture of consternation and delight they caused in academic physics circles was immediately evident, and a major theme of press coverage of both x-rays and radioactivity. At the same time, however, they promised to disrupt the established routines of nonscientists, as well—for good, for ill, and both at the same time. The sudden ability to reveal the flesh beneath the skin (and clothing) might be taken by any given contemporary observer as the worst possible affront to Victorian modesty, the harbinger of psychoanalysis and abstract expressionism, or as a transformative and wholly beneficial medical tool (or all three at once, or many other things besides), but few indeed seemed to doubt that x-rays would effect real changes in the conduct of daily life. Radioactivity was even more potentially disruptive: if, as Frederick Soddy and hundreds of other scientist-popularizers had it, a means could be found to release energy from radium at will, rather than the relatively stingy rate of half its reserves per 1,600 years, then the world would necessarily and radically change. Some chose to accentuate the positive potential of limitless energy in a world that could barely make do on coal; others followed the thought to its logical conclusion and braced themselves for all-powerful radium explosives. In either case, with very few exceptions (exasperated magazine editors, for example), the one point on which consensus about the rays was reached was that they would somehow transform *everything*.

On the question of how they would do so, however, there was virtually no agreement. Even the vocabulary was muddled: Were Roentgen's rays the "new photography," or "the new electric light"? Did one sit for an x-ray *portrait*, an x-ray *exposure*, or (as many had it) an x-ray *séance*? More fundamentally, Americans quickly had to take sides on the question of whether the new energies were physically safe. Here, too, there was floridly contradictory evidence, and it would have been easy for any given individual, charting an idiosyncratic path through the thicket of information available to him, to conclude that radium was a deadly and insidious poison, a stimulant and panacea without peer, or both or neither. Pierre Curie, one of the first to be injured by acute radium exposure, mused vividly to reporters about the horrifying massacre one could perpetrate with a sufficiently large mass of radium, simply by showing it to people. Yet Americans first learned of this anecdote from his American colleague William Hammer, who felt sufficiently optimistic about its medicinal qualities that he used family members in ad hoc experiments.[27]

Chapter 3 explores the years in which other, less well-connected kinds of families came to experience the new energies. X-ray mania, as judged by newspaper and magazine reportage, lasted several years into the twentieth century; enthusiasm for radium, which started in 1903, carried on at least through 1907. But it was only at the end of the first decade of the twentieth century that nonscientist Americans were able to begin systematically testing the chaotic maelstrom of impressions that had arisen during that time against physical encounters with the energies themselves. The indirect commercialization of radiation had already begun in the first years, in doctors' offices, lecture halls, and on the labels of things like "X-Ray stove polish." Technological improvements and economies of scale made medical x-rays a commonplace of the clinic, and broadened the range of conditions they were used for, but demand outstripped the supply of radiant medicine that orthodox physicians could provide, and a variety of hucksters and self-taught healers filled the void. Radium, which remained rare in the concentrated and refined doses necessary for orthodox cancer therapy, appeared profligately on the market in the form of health products that contained traces of the element, or only the promise of it on the label.

The popular iconography of radiation expanded quickly in the 1910s and 1920s. Newspapers and magazines continued to report tirelessly (if a little less breathlessly) on every new real and imagined use to which the rays might be put. Professional popularizers began to colonize the subject, too, and cheerfully escalated the expectations of their audiences about still-unachieved breakthroughs. In the process, they promoted a new kind of morality tale about the first generation of scientists who had worked with the new energies, transforming them into paragons of scientific virtue who had used their superhuman powers of perception—never missing even the faintest glow, the slightest smudge of exposed photographic film—to destroy the ignorance of what was now the old physics. These stories were amplified still further by the entry of x-rays and radioactivity into the school curriculum, where conservative textbook authors hesitated to speak too authoritatively on matters still under investigation, but were happy to repeat biographical accounts of the scientific ethos in action, and to stress, like the popularizers, the wonderful benefits that were just around the corner.

This new radiant hagiography found its way into the broader discourse. Poets, dancers, artists, and presidents all found occasion to talk about what x-rays and radium had done, were doing, and—most importantly—would soon do. The most unabashed speculation came, of course, from science fiction, which had a way of making even the most fantastic ideas about radiation seem like a simple matter of working out the details. Cheap weekly science fiction magazines so heavily relied on exotic rays and glowing transuranic metals to drive their plots and provide the requisite futuristic feel that their own readers sometimes protested the lack of originality, but science fiction authors were simply reflecting radiation's place in the zeitgeist.

The third phase of prewar nuclear culture, in which disillusionment and danger became the most prominent themes in the public discourse, is covered in chapter 4. Nuclear fears had never entirely receded, even while the word "radium" appeared promiscuously on labels, and x-rays burnished the professional standing of everyone from physicians to shoe salesmen. Radiation was responsible for a series of high-profile deaths, most of which occurred in the late 1920s and 1930s. X-rays decimated the first generation of radiologists; radium claimed the lives of industrial workers, tonic-drinkers, and one of its discoverers. Orthodox physicians had been concerned about x-ray and radium quackery from the start; they used the negative publicity generated by these deaths in a public relations campaign aimed at discrediting non-allopathic ray treatments. Their strange bedfellows in this endeavor were a sizable contingent of alternative healers, who portrayed medical radiation as a heroic therapy akin to calomel or bloodletting, effectively conceding the ground of radiation-based "scientific medicine" to the American Medical Association (AMA) while disputing its efficacy.

By the mid-1930s, the evidence before the public about the dangers of exposure was vivid and fraught with pathos. But in spite of the many opportunities that any given layperson might have to physically come into contact with these energies, it was not fears of insidious, environmental exposure that drove the change in public opinion: for almost everyone, it was even easier to avoid irradiation than to experience it. Rather, the deliberate attempts to shift the discourse gained traction from the fact that, 30 or more years on from the initial excitement, Americans' patience for the promised miracles had begun to wear thin. X-rays were the standard of care for fractures, and with radium offered a glimmer of hope to cancer patients that had not been there before, but nothing more. Throughout the 1930s and 1940s, newspapers ran articles about bigger and bigger x-ray tubes: rays generated by potentials of three hundred thousand, six hundred thousand, a million volts. The stories about these gargantuan machines, which often spanned several floors at newly constructed facilities, conveyed a certain awe at the audacity and immensity of the energies involved, but also dealt frankly with their marginal utility. A million-volt tube might be "a new weapon against cancer," but the laity had come to understand the difference between having a weapon and winning the war.

By the time Americans turned their attention fully to the Second World War, their understandings of the no-longer-novel radiations had only just started to cohere. X-rays were the docile servant of industry and medicine, useful and still inherently interesting, but no longer capable of surprising. Radioactivity was the wild child of nature, embodied in feral minerals with roughly the same degree of danger and utility as an unbroken horse. Modern science had not tamed it, though the effort to do so went grimly on. Progress in that arena came in unpredictable fits and starts, beginning with the spectacular unexpectedness of their discovery. The "naughty" rays' refusal to be effectively packed away in a black box, or rendered safe, or even be easily reconciled with the laity's intuitive physical understanding of the world, was a goad that made them perennially difficult to ignore.

* * *

Ionizing electromagnetic radiation and radioactive emissions are fundamentally different phenomena. As will become apparent in the central chapters of this work, the difference between the two as such was less clear in most laypersons' minds than was the distinction between *x-rays* and *radium*, the archetypal and most important exemplars of each. To a physicist, "radiation" means energy either in the form of waves or in moving particles, and might suffice as a blanket term for all the energies I address here (as well as several I do not, like neutron radiation and the electromagnetic spectrum of wavelengths longer than ultraviolet). However, because "radiation" is generally used colloquially today—and occasionally during the period under consideration—to mean ionizing electromagnetic radiation only, I will avoid that construction. In an effort to avoid repeating a tiresome but precise phrase like "ionizing electromagnetic radiation and radioactivity," I will refer to them variously as the novel energies, the rays, nuclear emanations, or other similarly inclusive constructions. This has the advantage of reflecting the persistent haziness that attended their usage in the newspaper articles, science fiction stories, and medical brochures that make up my sources. The population that drew its education from these sources could, past a certain point, be relied upon to know that x-rays and radium had some similar effects and applications (exposing film, for instance, or treating tumors), and certainly that the former was generated by machines and the latter by a naturally occurring substance. Most, however, would not know precisely the nature of the physical differences between the energies involved.

For the most part, this book will deal with x-rays and radium, and only incidentally with other forms or sources of radiation. Those two things attracted the lion's share of attention from the nonscientist American public, and they came to stand in for the broader phenomena themselves in virtually every instance. Many newspaper articles that took as their subject the phenomenon of radioactivity made no mention, even in passing, of any other element. Likewise, even as x-rays were slotted onto the electromagnetic spectrum, and understood by those paying attention to be different from visible light or radio waves only in their wavelength, virtually no discussion of them provided the laity with any rhetorical connection between x-rays and any other form of electromagnetic energy except for the gamma rays emitted from the nucleus, and later cosmic rays. There were exceptions to this rule, but they were minor and unrepresentative. Cosmic rays and thorium attracted some attention in the newspapers. Neutrons and antimatter were also duly digested for interested laity, but made no real impression on the collective consciousness. Ultraviolet light (also a form of ionizing radiation, although weaker in that regard than x-rays or gamma rays) was the center of rather more interest from health-seekers, but was usually understood as more similar to phototherapy, colored light therapy, or infrared treatments than to x-irradiation because of two things they all had in common: a visible light component and a weaker physical effect.

Finally, a note on scope and scale. It has been tempting, at various points in the preparation of this book, to make this a story exclusively about either ionizing electromagnetic radiation or radioactivity—that is to say, about x-rays or radium in early twentieth-century American culture, but not both. They are, after all, fundamentally different sorts of things to a physicist or a physician, or even to attentive laypersons, notwithstanding their near-simultaneous discoveries and the similarity of their effects on living tissue. For that matter, as the rest of this book will show, they developed very distinct identities over the course of their first half century: by the 1940s, radium's profligate energy seemed even weirder and wilder (and more sinister) than they had at first glance in 1903, while the x-ray had been steadily "tamed" until the threats it had first suggested in 1896 seemed remote indeed to most Americans.

For all those differences, however, they were practically identical in one very important respect: from the moment they first intruded on the consciousness of Americans, they were the heralds of a new kind of science—and a new kind of relationship between science, medicine, and their publics. True, that change had been coming for some time: x-rays were not the first disruptive technology to confront the Victorian world, and the recent construction of an educational infrastructure for the physical and medical sciences in the United States was already starting to introduce certain progressive expectations into the public discourse. Yet to the extent that Americans in 1894 had begun to look expectantly toward the laboratory or the machine shop for the latest development, they anticipated only clever refinements of things already known, or nearly known. If Albert Michelson's now-infamous declaration in that year that "most of the grand underlying principles have [already] been firmly established" was not *entirely* representative of his colleagues' opinions, it certainly would have seemed uncontroversial to a lay audience: futurists like Edward Bellamy looked forward to a year 2000 in which the chief technological accomplishment was a greatly refined and expanded telephone system.[28]

The new rays were something else entirely. There was no obvious limit to their utility. Their mechanisms were occult. They could barely be contained, and scarcely explained, by their discoverers, and there were no easy analogies to better-understood phenomena: radium was not *really* like fire in the way that an electrical telegraph was like a semaphore. Above all, the chaos their discoveries sowed in the recently complacent scientific establishment was clearly perceived by nonscientist Americans—something nearly as fascinating as the strange properties of the energies themselves. The new rays were, in short, the icons of a new and modern science in all its chaotic, fantastic, and ambiguously beneficial glory.

Chapter 2

Crazes

More than a century after their introduction to the world, the new energies of the late nineteenth century still strike most nonscientists as fundamentally weird. Intellectually, the notion of an invisible light, or that some of the basic building blocks of chemistry are unstable, is not so very difficult to reconcile with a high school-level understanding of science—although the fact that these phenomena are complicated exceptions to simpler rules has always relegated them to the back chapters of textbooks.

Intuitively, though, it is a different matter. Radiation has had many connotations over the decades, but a sense of incomprehensibility and mysteriousness has always been among them, and that sense—a pedal tone in the shifting chorus of voices of public opinion—dates back to the debut of x-rays in 1896. Their very unintelligibility, to scientists and laypersons alike, titillated Americans in newspapers and lecture halls nearly as much as their seemingly preposterous properties. This was something new under the sun. (Radium, a few years later, would be immediately hailed as something new *fueling* the sun.) Even those few commentators who could not muster up much excitement for the still-unproven technology, or who harbored doubts about its usefulness in healing the body, were nevertheless impressed by the fact that x-rays were positively deadly to scientific theory.

Radiation and radioactivity provoked interest of an intensity unprecedented in American history for a scientific topic. The radiations coming out of evacuated tubes and carnotite ore samples were not the most socially disruptive things to emerge from the physics establishment at the turn of the twentieth century. Mass communication through wires and the ether, electric illumination and motive power, efficient internal combustion, aviation, anesthetized and antiseptic surgery, the revolution in synthetic chemistry, old-earth geology, and perhaps a dozen other innovations can make a greater claim to having, for lack of a more apt phrase, changed the world as most Americans knew it. But these had been presented to the world outside of the scientific establishment as faits accomplis, the finished products of long teleological marches toward progress. Scientific journalism was a very tenuous medium in the United States for most of the nineteenth century; when it covered scientific matters at all, it rarely related more than the ends of the debates. The extended interregnum in physics and chemistry that x-rays and radioactivity provoked, however, had allowed nonscientists to observe, almost in real time, the excitement and frustration of scientific discovery and its aftermath.

This chapter is about those initial explosions of interest, and the almost endlessly broad and complicated tangle of impressions about the rays (and their discoverers) that flourished during this first flush of American nuclear culture. It is also about how that culture became self-perpetuating, independent of the laboratories that first characterized x-radiation and radioactivity, of the entrepreneurs and clinicians who first began using them, and of the print media that made them a staple of their science coverage. To borrow an analogy from a slightly later period in nuclear physics, that particular chain reaction came about not because of any of the properties or implications of the rays themselves, no matter how extraordinary they were, but by virtue of a critical mass of attention paid to them in those first years.

That attention was a function of accessibility. Americans' fascination with the new radiations was based on physical experience as well as rhetorical encounters, even in the early years of mania for x-rays and radium. Before the close of the nineteenth century, at hot springs and photography studios and especially at the doctor's office, the laity could and did conjure with radiation directly. The latter part of this chapter will consider the effect of that kind of experience on the nascent nuclear culture. Nevertheless, x-rays and radium were even more talked about than observed, and their near-daily presence in the periodical press during their respective crazes demonstrates the breadth of their reception by the public. The reportage on the Roentgen rays was neither uniform in narrative focus, nor consistent in tone, nor handled similarly from place to place or publication to publication. Yet by exploring the unguarded and divergent statements that nonscientists first made about the phenomena, we can gain a baseline perspective that allows us to see the particular forces at work shaping the narrative and, ultimately, bringing it into coherence.

The Press and "Radiomania"

The earliest mentions of the x-rays in American newspapers treat them with a mixture of curiosity and dismissiveness, very much in keeping with the press' general attitude toward scientific novelties in that period. In the middle of a much longer column on the state of affairs in Europe, Harold Frederic, a *New York Times* political correspondent, chided Kaiser Wilhelm II for summoning Roentgen to demonstrate his work with cathode ray tubes and awarding him a medal, when "already it is found that this discovery was . . . made by a Prague professor in 1885, who got an admirable photograph of Mont Blanc at dark midnight by virtue of the cathodic rays."[1] Frederic's report ran first in the *Chicago Daily Tribune* on January 19, 1896, on page 9; on page 38, a better-informed and full-length article, vividly illustrated with line drawings of skeletons posed in drawing rooms, told in the awed tones more characteristic of x-ray reportage about the furor that Roentgen's rays had caused among "photographers all over the world."[2] Such contradictions and confusions about the import of, or even the basic nature of scientific discoveries were perfectly typical of science reportage in the period.

European newspapers were the first to report on Roentgen's announcement, which allowed the weekly overseas digest *The Critic* to have nearly the first words in print from an American press, with its summary and commentary on the London papers' account of the Roentgen rays. Tellingly, it took the form of a tongue-in-cheek, yet not very lighthearted meditation on the loss of privacy that Roentgen's "chemical light" portended. "It is also said," wrote correspondent Arthur Waugh, "that this new light can penetrate human flesh. Mind-reading was bad enough, but here comes an instrument that can read the innermost secrets of the heart. . . . The possibilities of this new invention are terrible."[3] This uneasy humor was characteristic of many initial meditations on the rays, and demonstrates the broad range of emotional reactions the rays were capable of producing even from the start. The omniscience hinted at by the blurry and sometimes indecipherable skiagraphs reprinted by illustrated newspapers was spectacular, yet somehow ominous as well.[4]

The first few weeks of reportage about the Roentgen rays reveals the idiosyncratic and collectively uncertain response of local editors, who had nothing more to guide them with respect to this unforeseen and barely comprehensible transatlantic lab report than a general sense of what their readers might find interesting. They were also constrained by their respective judgments about how much science content their readership might find tolerable. The *Chicago Daily Tribune*, for example, made ray-coverage a mainstay, finding reasons to reference the rays far more often than its cognate papers the *New York Times* and the *Los Angeles Times.* A week after they made the first mention of Roentgen's rays in a US paper, *Tribune* reporters brought readers the story of two local brothers who claimed to have invented a photographic film that would see through objects using only normal light. Three days later, the *Tribune* ran an article on potential industrial applications; two days after that, it ran two articles on the rays (one semi-technical digest of the prevailing scientific theories about the rays, and one report on a lecture-demonstration), and the following day it ran two more pieces, including one speculating about the possibilities of an x-ray link to the "spirit world." By February 22, it had reached the limits of its saturation coverage with five separate articles referencing Roentgen and his rays, including literary notes (a book had "a perfectly transparent plot, requiring no X-ray to make it clear") and an account of a sermon (in which a character's "heart is too hard to be pierced even by a Roentgen ray").[5] While many of the *Tribune* ray-stories in that first year were of special local interest—area doctors reporting on x-ray-assisted diagnoses, or the continuing exploits of several employees of a local electrical company who were successfully experimenting with machines designed for sale to local hospitals—the decision to run so many stories and to so quickly fold ray-language into the vernacular of the paper reflected only the editors' intuition that their readers had an appetite for them. That the *Tribune* had read the situation correctly became apparent quickly as other large-circulation papers increased their own coverage of the rays.

In the smaller papers, however, coverage of the rays tended to wait until a local angle arose, something that occasionally took years. Anyone with access to Crookes tubes and a rudimentary understanding of electricity could build an x-ray-generating apparatus without much difficulty, which meant that Roentgen's experiments were quickly replicated in high schools, electrical plants, and machine repair shops. These sorts of experiments, especially if they seemed to produce unexpected results, were often the first mention of the rays in local papers. The *Fort Wayne Weekly Gazette*, for instance, forbore to mention Roentgen at all before December 3, 1896, when it reported on an hour's demonstration of an apparatus set up by a local photographer. Impressed, the authors devoted three columns, with illustrations and a considerable amount of technically detailed explanation of the rays' generation, before concluding that "it will occur to our readers that the community has a large interest in the apparatus herein described," and urging that the town or the nearby medical college acquire the rights to the use of the machine immediately.[6] The *Atlanta Constitution* published 21 articles on the rays in 1896, but it was an Auburn University professor's experiments that first attracted the attention of a reporter. The four-column, illustrated, adulatory piece pointedly noted that while Professor McKissick of Auburn had already produced clear x-ray images from a scratch-built machine, the New Jersey inventor Thomas Edison was "still busy in his preparations."[7]

Not all mentions of Roentgen's discovery were about the phenomenon itself. From the speed and imagination with which the popular press adapted the term "x-ray" for metaphorical use, the pervasiveness of the excitement that surrounded them becomes clear. Science reportage may occasionally slip into jargon, but editors of book reviews and the society pages do not permit allusions that their readers will not understand. The word was used profligately, almost carelessly, and in a wildly divergent range of tones that neatly capture the incoherence of the general public's initial response.

There was, for example, the connotation of *illumination*: "We don't demand beauty, we don't beg for brilliancy, we only politely request for a woman's face lighted with a single X ray of intelligence," an arts columnist wrote in March 1896.[8] A month after the rays had made the acquaintance of the *Chicago Daily Tribune*'s readers, one of them had written "to ask if the peculiar snow that fell the other night can be considered an 'X-rayordinary affair.'" The particular nature of that snowfall may be indecipherable from that reference, but the attempt to stretch the word around the rhetorical forms for *weird*, *strange*, and *unexpected* is perfectly clear.[9] By 1897, to "x-ray" a person was being used as shorthand for taking the measure of them: the "x ray of truth" revealed to *San Francisco Call* readers the inconsistency of William Jennings Bryan's tirades against the railroads.[10] And, borrowing against the *omniscience* the term was coming to represent, newspapers in Bedford, Indiana, and McAlester in the Indian Territories took the name *X-Ray*.[11]

* * *

"No word in the English language should be used with more caution than 'impossible,'" a book review in the *Carbonate Chronicle* asserted in 1901. "[T]he x-rays alone ought to be enough to convince of that."[12] Yet the early presentation of x-rays made clear just how difficult it was to establish the bounds of impossibility for such a thing. David Starr Jordan, president of Stanford University and a respected biologist in his own right, wrote in the September 1896 edition of *Popular Science Monthly* about the "sympsychograph," an invention of the "Astral Camera Club" of Alcalde, California. This refinement of the Roentgen ray, Jordan soberly reported, allowed the psychic impressions of the human mind to take physical form directly on photographic film. The magazine reprinted a dark, fuzzy image resembling a composite photographic exposure of a cat, the alleged result of one of several successful experiments. "It thus becomes clear," he concluded, "that the invisible rays of Roentgen are not light in the common sense, but akin rather to the brain emanations or odic forces without the intervention of forms of gross matter as a medium, and to which gross matter in all its forms is subject."[13]

Jordan had intended for this "gentle satire," as he later described it, to be an obvious bit of fun at the expense of scientific spiritualism—a "quiet laugh at certain absurdities heralded as science." The magazine's editor was in on the joke, but not many others were: as ridiculous as Jordan had tried to make the claim, the demonstrated properties of the x-rays were already too bizarre to be that easily topped. A clergyman announced a series of sermons on the lessons to be drawn from the discovery.[14] Pressed for comment by reporters, scientific spiritualists immediately proclaimed it a validation of their researches, while more orthodox scientists and engineers expressed a certain hesitating skepticism—but left themselves room to revise their opinions.[15] Without the ability to confirm things with Jordan, who was conveniently vacationing in Alaska when the story was printed, even his scientific colleagues were unsure about how far into unreality the x-rays might have taken him in the fraction of a year they had been known. Nor were Jordan's peers the only ones at risk of being fooled by such a hoax: The London Psycho-Therapeutic Society hosted a lecturer in 1906 who reported that rats, kept in hermetically sealed tubes on which Roentgen rays were shined, cast bony shadows only while they were alive. Shortly afterward, the Society retracted the story, saying that the lecturer himself had been fallen victim to a hoax.[16]

Given that the maelstrom of notions about x-rays included many that dealt with the connection between the energy of the rays and the vital energies, the assertion that living tissue and dead might cast different shadows was hardly farfetched: this was, in essence, the same claim that was being seriously advanced by the physicist Pierre Blondlot and others for the N rays.[17] These were emissions from heated bodies, first reported in 1903, that Blondlot and some of his colleagues believed could be made barely visible in a darkened room. Further research led to the conclusion that the N rays were "stored up" in certain substances, especially living tissue or organic materials like green wood, and emitted later. The popular press kept a close eye on the phenomenon, and conflated them with radium and x-rays. "Looking through the skull of a man and seeing the workings of his mind is an achievement that Prof. Blondlot of Paris has succeeded in attaining by aid of the newly discovered 'N' rays," the *Chicago Daily Tribune* noted in a half-page illustrated article that characterized the N rays as fulfilling the potential for physiological omniscience that x-rays only had hinted at.[18] Commenting on a recent *British Medical Journal* article, the *Christian Observer* wondered aloud whether the "physiologic *n* rays" with their "possible bearing . . . on theories of thought-transference" would "eclipse both x-rays and radium as a popular sensation"—which would indeed have been an unprecedented thing in the annals of science popularization.[19] The *Los Angeles Times* reacted by situating the N rays in a pantheon of emanations and apparitions that included x-rays, spiritualist manifestations, and auras of a less physical sort: "Blondlot and Charpentier discover the N-rays which are given off by living human beings. . . . Now will all you rationalists still declare that the blue or golden halos around the heads of the chosen were nothing but the invention of religious simplicity?"[20]

Though serious doubts were being raised about the reality of N rays within a year of Blondlot's announcement, newspapers and journals continued for several years to run regular reports on them. Blondlot's rays offered the tantalizing possibility of a marriage between old-fashioned vitalism and the sense of scientific modernity attached to x-rays and radium rays. Newspapers noted that scientists had discovered that N rays were suppressed in the presence of anesthesia, or that yet another species of living ray (the "I ray") was produced by human cognition.[21] The ground had been cleared for a thoroughly vitalist understanding of rays of every sort, both in the lay public and in the emergent scientific medicine movement. If the 1898 report that Japanese glowworms seemed to emit rays of equal penetrative power to a Roentgen apparatus failed to capture the public imagination, neither could it have seemed entirely farfetched, so quickly were ray-energies bound up with life energies in the general public understanding.[22]

Within just a few months, the word "x-ray" had acquired a fantastically broad connotative range. As the expectations and apprehensions about the rays' potential applications piled up, mutually exclusive or otherwise contradictory beliefs coexisted comfortably in the public discourse. X rays were, depending on the source, any of the following: a purely electrical phenomenon, an innovation in photography, or a manifestation of the subtle, spiritual planes that scientists like William Crookes had been investigating. If their discovery was in one article a triumph for modern science, it was a death blow to outmoded theories in the next. The rays were simultaneously held to be deadly to living things, and a physical instantiation of the life force itself. (By way of proof of those kinds of claims, reports of early experiments had x rays killing live laboratory mice and reviving dead ones.) Their study was held to be the province of elites like Roentgen and Edison, but somehow also of high school teachers and the bolder class of photographer. The "new omniscient agent" inspired dozens of articles on what it could not see through; every enthusiastic speculation about a yet-unrealized application of x rays was an invitation to an article about x-ray hoaxers. Even the most minor elements were contested: headlines proclaimed that x-ray exposure would grow hair ("X Rays for Bald Heads: New Use Discovered for the Wonderful Agent," *Daily Tribune*, November 29, 1896) and remove it ("Baldness Due to X-Rays: Such is Believed to be the Result from Experiments Made to Locate a Bullet in Henry Cohen's Head," *New York Times*, February 4 1896.)

X-rays, in short, could and did mean almost anything to anyone who had heard of them, and in spite of this fact (or perhaps because of it) they continued as a collective idée fixe for years. *Popular Science* declared 1897 the "Year of the X Ray" which surely seemed more and more premature as each subsequent year brought more attention to the phenomenon. The press, which from the start had been folding commentary on the craze over x-rays into its accounts of the rays themselves, took note of the fact that readers seemed to agree on little about Roentgen rays other than that they wanted to hear more about them. Science journalist Waldemar Kaempffert once criticized the science editor's "stock argument that he 'gives the public what it wants.' But does he really know what the public wants?"[23] Editors were never surer than they were with the x-rays. This was sometimes expressed as pique, or a pantomime thereof, as with the *Pall Mall Gazette*'s March 1896 tantrum that began, "We are sick of the Roentgen rays," and proceeded to suggest that x-ray machinery (if not its inventors) be thrown into the sea.[24]

Wry humor, often with an air of resigned weariness, was another way that editors dealt with the flood of x-ray news. But the standard explanation, when one was offered, was simply that the exigencies of reader demand necessitated the blanket coverage. The *Nebraska*

State Journal, reflecting on the role of daily newspapers, opined, "The daily simply reflects the state of the public mind. . . . If they would lead, they must follow, and not discuss European politics when people are interested in home politics, nor Trilby when the world is excited about the Roentgen ray."[25] The urgency was not limited to the daily press: popularizing books on related subjects that had been printed before Roentgen's announcement were rushed into revision. The second edition of *Electricity for Everybody* included a new, hastily written chapter on x-rays and a note dated November 1896, implying that they had been deliberately excluded from the 1895 edition on the grounds that they were "previously almost [*sic*] unknown."[26] That was, of course, impossible; the book would have been sent to press months before Roentgen's first communications on the subject. It was a minor error, but a telling one. Possibly, the author was unwilling to believe that so momentous a thing as Roentgen's rays had really been entirely overlooked by modern physics, and wanted to conceal the shameful fact that he had only learned of them along with the rest of the general public. But it also seems plausible that his memory was simply being overtaken by events: so much ink had been spilled on the x-rays in just the first few months of 1896, and in such a collectively incoherent fashion, that it would have been easy to mistakenly conclude that it had actually happened over a much longer period of time.

Radium Enters the Picture

A minor undercurrent in the first few years of popular discourse about x-rays was their apparent emanation from certain fluorescing minerals—that is to say, uranium compounds and the various ores in which uranium was present. Becquerel had characterized the x-ray-like emissions from uranium in 1896. Marie Curie had coined the term "radio-activity" for the broader phenomenon shortly afterward, and the Curies isolated polonium and radium from uranium ore in 1898. This was reported sporadically by the popular press, but with none of the urgency or excitement that had attended the announcements around x-rays. Radium and polonium were simply two new isolates of uranium ore that shared its as-yet unexplained property of ionizing the air and exposing photographic plates. At most, they were treated as a more convenient means of radiography, as though an x-ray machine had been melted down into mineral form. An 1899 article on these new metals that waxed relatively enthusiastic about their photographic applications, mentioned in a distinctly desultory final paragraph that radium "apparently violates one of the fundamental laws of physics, namely, that of the conservation of energy."[27]

Not until 1903 were the implications of that sort of thing brought into focus for the general public. That year, Becquerel and the Curies were jointly awarded a Nobel Prize, and in June, Soddy and Rutherford's findings that radioactivity was a form of atom-by-atom transmutation became known to the public. The emerging scientific consensus that atoms were transmuting, decaying, or otherwise evolving seems to have been the catalyst for much more intense reportorial attention. Before, these new metals were minor wrinkles in an otherwise smooth scientific landscape. Suddenly, like the Roentgen rays they seemed to emit, they were extraordinary threats to the status quo. Almost simultaneously, in July 1903, reports began to surface on both sides of the Atlantic of cancer cures accomplished by use of radium in place of x-rays.

Consequently, newspapers were flooded for the second time in less than a decade with reports of and speculations about fantastic and mysterious rays. The radium craze followed much the same channels through the press landscape as the x-rays had, with the addition of a mild note of self-awareness the second time around. "The radium craze is having its run through the news weeklies and monthlies of the world" the *Wichita Eagle* sardonically began an editorial blurb a few months into it. "The x-ray it seems must give way to the Radium ray as a cure-all, at least until such time as something still newer shall have been discovered."[28] The article then immediately listed the virtues of radium as a cancer therapy; the barb was not at the discovery but at its reception. The following month, a tongue-in-cheek article appeared in a Buffalo newspaper about a man who presented himself to a police sergeant as the representative of the Queen of Bavaria with $240 billion worth of radium (or two tons at the going rate) to sell, whereupon he was remanded to an insane asylum. "Aside from the humorous phase of his case," the item continued, "there is a serious side to it. Since the discovery of radium he has been perplexed by it and has studied both night and day...he has allowed the subject to absorb his mind. He has gone daft upon the subject."[29] The obvious editorial position of the article—it is not clear whether this is a fiction or a whitewash of an actual event—was that society was in a milder state of the same daftness. The editors of *Life* acidly noted that for all the talk of curing cancer—and curing everything else—to say nothing of transmuting metals and divining the sex of fetuses, "its greatest value right now seems to be as a basis for wonder stories. For our part, we are going to grub along for the present, struggling as heretofore to solve the problems . . . of existence, just as though there were not a grain or two of radium in the world."[30] For several years, though, this promise was more than most newspapers or general-interest magazines could fulfill.

The connotations of light that attended radium in the early years of the 1900s (then, as now, frequently and incorrectly described as something that glowed itself) made stories of its use as a blindness cure especially compelling. The apparent restoration of a seven-year-old Austrian girl's sight by a combination of radium and x-ray therapy made for headlines in many domestic newspapers, thanks in part to the participation of American radium popularizer William Hammer. Underneath the banner headline, "She That Was In Darkness Tells How By Radium She Saw The Light," the details of Tillie Spitznadel's treatment were somewhat less dramatic. After her treatment, Tillie was able only to make out the motion of bright lights. Nevertheless, the half dozen or more independent reports that reached American readers all stressed the raw power emitted by the tubes of radium that were strapped to her head, whose rays penetrated her brain from three sides and revitalized her necrotic optic nerve. The prose was breathless: "In the first experiment on Tillie Spitznadel's eyes a 7,000 radio-activity was employed. In the next and supreme test the incomprehensible power of 300,000 radioactivity will be used!"[31] Eventually, Spitznadel's mother, annoyed by the notoriety her daughter's case was attracting, eventually appeared in the papers to rebut the idea that there had been any real improvement. The apologetic subhead in that story—"SORRY, BUT SUCH IS FACT"—is itself fairly vivid testimony to the eagerness with which radium miracles were anticipated.[32] (See Figure 2.1.)

Notwithstanding the elder Spitznadel's contrary note, miracle stories continued to appear. From Russia, two months later, came word of two blind boys whose sight had likewise been restored by a sort of radium phylactery.[33] Domestic success followed with the radium cure of a Philadelphia man's blindness from "nervous shock."[34] The theory on which the medical doctors operated with regard to radium and eyesight is not much discussed in any of these stories, but the message for the laity is clear enough: radium produced miracles of a flatly biblical nature merely by being in the vicinity of a body. No radium-Lazarus came to the attention of the daily press, although the *Chicago Chronicle* did note the possibility of radium-impregnated woolen clothing by which one might be "cured in the most delightful way possible," albeit by contact with the whole of the garment and not merely the hem.[35]

CHILD WHOSE SIGHT HAS BEEN PARTIALLY RESTORED BY RADIUM.

LILLIE SPITZNADEL

"Newark Evening News." Newark. N.J. 8.24.03.

RADIUM MAKES BLIND GIRL SEE

Remarkable Results Are Obtained with the New Metal and the X Rays.

SIGHT LOST FOR EIGHT YEARS

She was stricken with blind
when three years old after a long
ness due to meningitis, and for se
years now has been a pupil in a s
for the blind in Hartford, Conn.
plays the piano, sings and is accom
ed as far as so young a child can
the things that the blind learn at th
stitutions devoted to their instructio

The child's eyes are wide open and
clear. Indeed, it is impossible for a c
observer to tell that she is blind a
Shortly after she was stricken, she
examined by Dr. Hamilton Knapp.
said that although her right eye app
to be in better shape than the left, he
no hope for her ever recovering her
The child has been under Dr. Jenk
care for some time. He is much inter
in radium and has made many ex
ments with Mr. Hammer, who h
laboratory at 153 West Forty-sixth
devoted to work with radium.

Dr. Jenkins and Mr. Hammer de
that little Lillie Spitznadel was a
ceptional case for experiment, and
Wednesday night the girl was taken.

Figure 2.1 "Radium Makes Blind Girl See." One of many miracle cures attributed to radium.

Radium was so incompletely understood by those taking down the pronouncements of lecturers and experimenters that it is sometimes difficult to know which of its initial palette of attributes had any basis in an actual laboratory examination, and which were pure fantasy.

Like x-rays were reported to do, the penetrating rays of radium distinguished real diamonds from false ones—so said the unnamed "discoverers of radium," reported the *Syracuse Telegram*.[36] The expectations about what radium might be capable of did not discriminate according to scale. Pierre Curie, to whom another paper attributed the gemstone discovery, was also fond of talking about how a few pounds of radium, properly applied, would suffice to destroy the city of London, drive two thousand locomotives, or even kill all animal life on the planet.[37]

For all the extravagant expectations about the physical properties of radioactive substances that were given voice in early news reports, nearly as much ink was spilled on their economic properties. The astronomical cost of radium was as surprising and exotic a thing as anything else about it, and one of the more easily understood aspects of its strangeness. Where writers struggled to convey the magnitude of the energy radium contained—was it enough to say that its force ripped atoms asunder, or was it better to phrase it in terms of battleship-propulsion-miles-per-teaspoon?—there was no ambiguity as to what a figure after a dollar sign meant. The cost cited varied widely: three thousand times its weight in gold, $1 million per pound, $*14* million per pound, a million times the cost of an equally radioactive quantity of thorium, and so forth.[38] (With that sort of hyperbolic cost, the readers of the *New York American* had no trouble understanding why the chief US tariff official wanted to impose a 25 percent duty on the substance.[39]) Of course, as the *Washington Post* harrumphed in one of its radium frenzy-backlash articles, while it was true that mere millionaires could not afford radium, "likewise, millionaires may not buy the moon." Yet it was also true that appreciably radioactive preparations of radium barium carbonate could be had for $1.50 a grain; the expense was really the result of the difficult refining process needed to make relatively pure radium compounds.[40] The perception of radium's rarity and preciousness, reiterated practically every time the word appeared in print, was such that it was ten years after the initial craze before *fraudulent* commercial nostrums containing "radium" were commonplace, and then only with caveats that they contained extremely small amounts of the stuff, lest prospective buyers become suspicious.

* * *

Radium was even more susceptible to vitalism than x rays and N rays had been. In the pages of newspapers and magazines, radium was characterized as not simply being an adjunct to life, but virtually a living thing itself, if not a personality in its own right.[41] *Harper's Weekly* put the question bluntly: "If anything in the world is alive, is not radium alive?" For the medical doctor who wrote those words, radium represented the first hint at a third way between the equally fruitless "old materialism" and "old vitalism."[42] Nor was this a novel editorial tack for the magazine—in 1902, reporting on radioactivity for the first time, it had concluded (apropos of little in ten pages that had preceded it) that there was "one thing we do know—space is all aquiver with waves of radiant energy . . . what has been called the 'harp of life.'"[43] Following that theme, the news in 1905 that John Burke of the Cavendish had apparently produced life in sterile bouillon by seeding it with radium commanded a great deal of commentary in the popular media. Even William Ramsay's gentle refutation of Burke's initial findings carried the caveat that "no one will rejoice more than" the eminent chemist if further study were to reveal that Burke had succeeded after all in demonstrating radium's literal vitality.[44]

A *Literary Digest* reprint noted the variable radioactivity of the parts of the human body (brains superlatively so; kidneys to a lesser degree) and noted that one's social position did not especially correlate with bodily radioactivity.[45] Another reviewed a study of the apparent power of radium to revive dormant plants, a theme that would later be reprised by manufacturers of ersatz "radium" nostrums, who were fond of using dramatic before-and-after images of plants supposedly revived by exposure to radium. "It must rouse our greatest interest that this wonderful element, which has had such a revolutionary influence in the domains of chemistry and physics, should also exert so profound an influence by means of its invisible rays on living substance," averred the scientist behind the plant study, but to judge by the popular media, radioactivity was as much a biological thing in the public mind as it was a creature of the chemistry or physics lab, if it were to be associated with a science at all.[46]

The sense of vitality that attended radioactivity provided clergy with a potent and timely metaphor, which they explored in sermons and public addresses that frequently found their way into circulation through the daily papers and sectarian magazines. From the first flush of the x-ray craze, when the word was on everyone's lips, clerics had reached frequently for the handy reference to omniscience. On one day, the Chicago papers noted two sermons preached that referenced the rays: at Fifth Presbyterian, it was said that Christ's presence, "like the X ray, searched to the bone of things, and presented a picture of hideous forms in the human heart," while elsewhere Rev. Crane noted the x-ray's ability to cause fluorescence in an elegant extended metaphor that concluded with the sentiment that "Christianity is not a culture, a philosophy, a belief, a conduct, but a character set aglow with a divine ray." But the reference proved durable; magazines like *Christian Century* and *Zion's Herald* also employed it.

Radium, likewise, suggested the divine to many of its chroniclers, not merely for its miraculous properties, but for its intense and penetrating energy. To observe that "radium Christians are constantly giving off energy," conflating the mystery of the holy spirit with the mystery of radioactivity was, for most Americans, to intermingle secular and spiritual superlatives of the highest order.[47] Or perhaps the stuff itself was such a commingling: "The radium seems to suggest that we have penetrated the sanctum sanctorum, that we are face to face with the mystery of mysteries," the *News-Leader* of Richmond, Virginia wrote.

> And we are now treating it, handling it, using it, carefully, cautiously, observing, for all the service it may do to mankind. It seems to be spirit and light itself. How strangely, marvellously, suggestive of the Great Original; of God tabernacled in the flesh; of Him who brought light and immortality to life; in whom was life, and the life was the light of men.[48]

Analogies to the Holy Spirit fit well with another idée fixe of early newspaper coverage of x-rays and radioactivity: the possibility that these strange, unpredictable, and apparently vital emanations were connected with the equally bizarre, ephemeral, and lifelike phenomena of the spirit world. Press coverage tended to be skeptical; by 1895 the worm was turning against the spiritualist movement in the United States, and had long since done so on the continent. Still, the number of words that linked energetic rays (especially the "ghostly" x-ray) with spiritual emanations testify to the currency of the idea in the public sphere. To some extent, the association would have existed simply because of the similarity in which spiritualists and scientific lecturers presented their material: both featured darkened rooms and wispy glows for dramatic effect. For instance, a Parisian lecture-demonstrator in 1897 featured a faux "séance" with eerie light effects that were subsequently revealed as x-ray-induced phosphoroluminescence in glass.[49] The American Society for Psychical Research (like its European counterpart, an organization populated by respectable scientists) urged newspaper readers to keep an open mind with respect to a possible connection between the two realms that, seemingly, grew ever closer. Its president James Hyslop wrote that

> the whole subject of psychical research, covering all the unusual phenomena of mind, promises to give a meaning to the cosmos which is

> not dreamed of in physical science. Of course, the latter has opened up a universe of occult material forces, such as wireless telegraphy, the X-ray, the N-ray, radio-active phenomena, and ions and electrons, all of which make it but a slight step to believe in the possibility of spirits.[50]

Oliver Lodge, no small celebrity himself as a pioneer in telegraphy, extended the connection to radium: if thought and life were manifested by the reorganization of molecules in a brain or body, he mused, might not the spontaneous reorganization of radium's parts be evidence of "the Mind that actuates the universe?"[51]

Spiritualists, whether of scientific bent or not, were only too happy to further the association between barely perceptible emanations both physical and psychical, and those who claimed to manifest abilities like clairvoyance or telekinesis were generally as willing to submit to x-ray examinations of spiritual phenomena as they had been to electrically based tests.[52] The allusions faded from the public sphere along with the scientific spiritualism movement itself, but the use of the term "x ray séance" to denote a medical examination using the rays remained common.[53]

Iconoclastic Rays

The sole common thread that linked virtually all discourse about the x-rays and radium was that they were disruptive of the established order of things. For turn-of-the-century audiences, the natural world might be serene or terrible, but it was understood to be rational in its way: the mysteries of nature were nevertheless bound by certain inviolable rules. Laboratories, artificial spaces in which scientific "wizards" put nature to the test, connoted solemnity and rigor. The new rays upset consensus and flouted the laws: they were, as a much-reprinted poem in the magazine *Photography* put it, *naughty.*

> *The Roentgen Rays, the Roentgen Rays*
> *What is this craze:*
> *The town's ablaze*
> *With the new phase*
> *Of X-ray's ways.*
> *I'm full of daze,*
> *Shock and amaze,*
> *for now-a-days,*
> *I hear they'll gaze*
> *Through cloak and gown—and even stays,*
> *These naughty, naughty Roentgen rays.*[54]

Like so many of the reactions to the rays preserved in print from that era, the poem reflects a mixture of incredulousness, humor, and at least a little anxiety. It also expresses the idea that things would be fundamentally, irretrievably different in the age of the x-ray. This sense of being present at the passing from one technological epoch into another was observed by Americans in real time. A Marietta, Ohio clothing store's April 1896 ad committed to print this capsule observation of emergent nuclear culture: "X-Rays: A year ago were an unknown quantity. Two months ago, there were millions of people who doubted the existence of any such wonderful phenomena. Today, no person of intelligence doubts the existence of these wonderful rays." This was in service to an analogy linking Roentgen's discovery to the store's opening: "Today there are but few—indeed a very few who do not know of THE BUCKEYE and its X-RAY-LIKE (wonderful) BARGAINS."[55] The comparison might have been facile, but it was an accurate appraisal of the public understanding of Roentgen's rays at the moment: that the landscape had been permanently changed by them in some (wonderful) way.

Because they had shattered the scientific consensus of the nineteenth century, the new radiations quickly became indelible icons of the new paradigm that replaced it. They became shorthand for modernity, however one chose to regard that. One hallmark of early reportage on both phenomena was the emphasis on *newness*. The x-ray was, variously, the new photography, the new electric light, the "new omniscient agent," and so forth. Often the emphasis was not on the novelty of the rays themselves—that was self-evident—but to their renewing effect on established fields of endeavor. *Cosmopolitan*, exactly the sort of general-interest magazine whose printing of stories about x-rays and radioactivity marked the phenomena as unusually significant for science stories, printed its first article on the rays in 1897 as part of a retrospective titled "Advances in Photography During 1896." For *Cosmopolitan*, the significance of the rays was not their inherently fascinating property of rendering the invisible visible, or the tantalizing hint that they were somehow bound up with the animating force of life, or even the practical expediency of setting bones and finding bullets in flesh, but rather that they promised to unite the discipline of medicine with the practice of photography, in the process revitalizing both.[56] The *New York Times* cheekily noted the inability of language to keep up with the developments in emanations: "The X rays, the Finsen [ultraviolet] treatment for lupus, the operation of radium for cancer, and what not—what are the words for these? A man is guillotined or hanged, his leg is amputated, he is trepanned. What is it when he is rayed, finsened, radiumed?"—but behind the humor was an acknowledgement of how quickly things had changed.[57]

With radium in particular, reporters favored terms like "revolutionary"; from the start it was assumed in coverage that it would in short order cause upheavals in medicine, physics, and industry. It was a cliché of early x-ray discourse, too, that they portended radical change to the routines of everyday life, and perhaps to the social order itself. Some of this arose from tongue-in-cheek or sensationalist reportage claiming that x-rays could reveal a person's thoughts or character, or the ubiquitous cartoon trope that x-rays worked by making the things they shone upon transparent. These were not, by and large, taken literally by their readers. Virtually every history of x-ray reception wryly notes the story of a state legislature taking up (or, variously, passing) a bill banning the use of x-rays in opera glasses. This anecdote is so commonly retold that it has occasionally been labeled apocryphal, but in fact it appears to have been genuine: the *Electrical Engineer* reported in February 1896 that Assemblyman Reed of Somerset County, New Jersey, had introduced just such a bill—as a joke.[58]

He was hardly alone in exploring the rays' comedic potential: in the same month, one could find in the newspaper illustrations of maids revealed by x-rays to be listening at doors, or the facetious suggestion that 1896's sudden shortage of Crookes tubes was the result of burglars buying them up.[59] (See Figure 2.2.) The *New York Times* deadpanned that some doctors' early resistance to using the rays sprung from the fact that they would instantly reveal the physical cause of all physical and moral deficiencies, including "cussedness." The same article repeated a little poem from the *Indianapolis Journal* surmising that "now the timid, doubting suitor / by Professor Roentgen's art / May, before he speaks, discover / If she has a marble heart."[60] This sort of uneasy humor was characteristic of many initial meditations on the rays.

Taken as a whole, the jocular tone of these reflections leaves the impression of a culture whistling past the graveyard. In those first few months when x-rays were encountered almost exclusively in breathless newspaper articles, when the upper bounds of the rays' omniscience had yet to be established, humorous speculation about absurd extremes provided the comfort of a worst-case scenario. As Bettyann Kevles has demonstrated, the threat that the x-rays presented to late-Victorian modesty was capable of producing real discomfort. This becomes apparent in those ruminations that did not take advantage

Figure 2.2 "The Wonders of Radium, Practically Applied." Just some of the whimsical applications imagined by cartoonists at the dawn of the radium craze.

of a veil of nervous humor. The *Chicago Tribune* reported that Walter Besant, a popular author,

> is not enthusiastic over the new X ray and its results. He says the more he thinks about it the more uncomfortable he feels. He shudders at the thought that the prying eye of science, not content with laying bare our bones, will spy out our thoughts, dreams, ambitions, loves, jealousies, and other emotions, record them, and file them away for future reference.[61]

The fears attributed to Besant here are telling: he is not concerned with an *actual* technology, but what the x-ray portends for science's further reaches. X-rays were not the only technology of surveillance to make its presence felt in 1896: photography, anthropology, sound recording devices, and rational medicine, among others, might have contributed to Besant's sense that the individual was being increasingly "laid bare" by science's "prying eye."

* * *

Laypersons who saw the x-rays as upsetting the apple cart found that their impressions were confirmed by their doctors. In medicine, x-rays portended sweeping changes, too: not merely for their immediate applications in setting bones and finding foreign bodies, or for their still-unexplored diagnostic and therapeutic potential, or even for the still greater miracles that patients and physicians unsubtly hoped would result from their use. Physicians also quickly realized that the x-rays also represented a potential coup de grace in the long struggle for the character of American medical practice.

In its first communication on the x-rays, the *Medical News* had perceived little of immediate value to physicians—an understandable misapprehension given that it was February 1896, too early for most laypersons to be absolutely certain that the reports were really genuine. But they had perceived clearly the threat that "charlatans" would use x-rays, or simply the mention of x-rays, to swindle patients. The AMA had similar thoughts about the technology that had "already become the plaything of the popular imagination," and that consequently there would "doubtless be an extensive advertisement of cathode ray baths, X ray treatments, etc., but it is to be hoped that any active exploitations of these will, until the matter is more elucidated by accurate scientific researches, be confined to the irregulars who have no standing in the regular medical profession."[62] That hope was in vain: both regular and irregular practitioners began experimenting with abandon, and advertisements for x-ray services of varying degrees of orthodoxy promptly began appearing in the newspapers. In any event, the distinction between charter radiologist and x-ray quack in the early years might have been almost impossible for a prospective patient to make, especially given that roentgenological services were often supplied on contract to physicians by photographers or other nonpracticing entrepreneurs.

The first medical applications of x rays, which began to take place within months of Roentgen's announcement, usually occurred as a consequence of local circumstances, rather than a broad and deliberate adoption of x rays as the standard of care. Typically, a physician in a given place had a patient with a complaint uniquely suited to resolution by x ray imaging, and that physician happened to know of a means by which an exposure might be made—say, by a scientist or photographer who'd taken to working with the rays, or a local electrical hobbyist. Needles embedded in feet, or similar complaints, provided many doctors with their first chance at interpreting a skiagraph. Doctors who had previously purchased electrotherapeutic cabinets, and therefore had all the makings of an x ray generator except for a modified Crookes tube, were relatively well-positioned to get into the business of x-raying, but physicians were only one part of the early medical radiology community.

The remainder was a mix of scientists, high school teachers, photographers, and electricians, motivated by both experimental and entrepreneurial spirits. Because film or glass plates exposed by the x rays still needed to be skillfully developed, radiology in its first decade favored those with skill in photography. Once photographers had set up an x ray apparatus, they could receive referrals from local doctors, and so "Roentgen studios" were established to meet the needs of a local medical establishment (and, not insignificantly, anyone else who cared to pay for x ray images or themselves or their possessions).[63] Often, these upwardly mobile photographers took on the work of interpreting the resultant images, too. For fractures and other relatively straightforward matters such as could be resolved by the skiagraphs of the first decade, the trained physician's command of anatomy was unnecessary, and so a class of lay technicians established a claim on the professional territory that the rays had created.[64]

Consequently, orthodox physician-radiologists worried that their facility with the apparatuses was allowing non-physician skiagraphers to usurp medical prerogatives. A few of those first generation of entrepreneurial photographers had taken the trouble to earn a medical degree, but most were simply businessmen hanging out a shingle to take advantage of an increasing demand, and—worse, from the perspective of the medical community—some were failed or disgraced physicians, who combined suspect medical credentials with a lack of technical aptitude in an attempt to succeed as an "x ray doctor" where they had failed as a regular one.[65]

Furthermore, many physicians who began offering x ray services in the first flush of their commercial availability were themselves complete novices with respect to the equipment that produced them and had no better notion of the physics involved than any other non-scientist, if only because the physical properties of the rays were far from established. With a few notable exceptions, the first generation of "x ray doctors" had far more in common with the sensibilities of their patients with respect to Roentgen's rays than they did with physicists of their day or the radiologists who would ultimately supersede them. Even for well-equipped doctors, the initial foray into x-raying was usually assisted in some way by someone from outside the medical community. An early textbook aimed at doctors who were adding x rays to their practice advertised itself as being "intended for the general practitioner who, having purchased an electrical outfit and desiring to make use of it, finds himself hopelessly at sea, not only in applying his various rays and currents, but in the use and care of the machine itself."[66]

Within a few years, it became clear to physicians that their patients, if not all of their professional brethren, had come to regard use of the x rays as a sign of forward-thinking medicine. "Let us be up-to-date physicians—twentieth century physicians if need be," one pioneer radiologist urged, because "the time is not far distant when our patients will not be content to believe our unproven statements. The public is becoming better educated. The days of magic and mystery in medical practices are numbered. Let us take a step forward toward diagnosing our cases with greater certainty before our patients begin to leave us or before the public drives us to use an x-ray machine. Let us welcome the dawn of public enlightenment (and our own) with an x-ray illumination."[67]

* * *

The popular (and professional) belief that x-rays would radically change the nature of medicine was furthered by the advertisements of those independent, variously legitimate x-ray clinics. Orthodox physicians were discouraged from advertising, but nonmedical or quasi-medical operators worked under no such restriction. They used that freedom to make claims approaching omniscience on behalf of their equipment. To attract crowds of patients, itinerant patent medicine vendors like the "Bi-Chemic Physicians" needed only a picture of a fluoroscopic screen being held up to a rib cage in front of an impressive-looking device, some accompanying text inviting the public to "find out for an absolute certainty just what your trouble is," and the constant reassurance that their x-ray machine was *scientific* (indeed, "the most elaborate and complete" such machine in the country). The inducement wasn't subtle; under the banner "FREE X-RAY EXAMINATIONS," the proprietors explained in large print that they were able to "cure because, *first*, they make an accurate diagnosis by the aid of their famous x-ray apparatus, and *second*, the reliability of the wonderful Bi-Chemic treatment."[68] From both ends of the spectrum of medical orthodoxy came the same message: everything would be different now. (See Figure 2.3.) X-rays had been deemed the essence of modernity by both proponents and opponents.

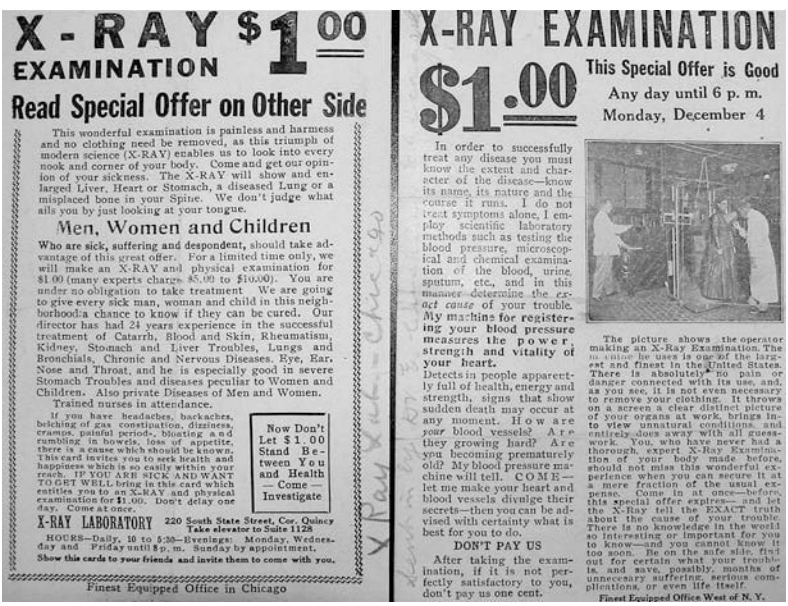

Figure 2.3 $1 X-ray examinations. Only hundreds of feet from the AMA's headquarters in Chicago, this less-than-orthodox x-ray clinic may not have cured many patients, but it and others like it raised their expectations for what x-rays might do.

As connotatively flexible as radiant energy was in its first years, it was still tightly rhetorically bound to the sites of its discovery and production, and the curiosity that laypersons felt about the new energies was closely linked to their interest in the scientific community. The havoc that the discoveries of Roentgen and Becquerel had wrought in the physics community unfolded within view of the American public, which at the turn of the century had come to regard its nascent scientific establishment with a varying mixture of amusement and respect. A few decades later, the influence of both the scientific establishment and the very notion of science had become enormous. Even those who dissented from the broadly optimistic general point of view with respect to the fruits of science and technology, or who refused to become entangled in the tentacles of the "medical octopus," or who had specific reasons to fear obsolescence or marginalization from new technologies nevertheless acknowledged that the authority of science was both great and increasing. In the words of Harry Emerson Fosdick, a prominent social commentator in the 1920s, science was "the arbiter of this generation's thought," in spite of some qualms about that arbiter's legitimacy.[69]

What accounts for the striking surge in the cultural influence of science? More than just x-rays and radium, to be sure, but they were especially relevant to the forces at work. One of the most potent claims made by scientists of the twentieth century, now true in a literal sense where previously it had only been symbolically true, was that they had superhuman perceptions.[70] They could, sometimes with the help of arcane instruments that only members of their order could properly manipulate, see things that no one else could see. More and more, science and medicine were oriented around the quite literally imperceptible: detecting minute changes in blood chemistry, perceiving the component parts of the atom, or measuring the seemingly infinite speed of light as it passed through an undetectable ether. Obviously, the discovery of the new energies fit the bill nicely. All the uranium in the earth's crust (and there is quite a lot of it) had not managed to make radioactivity known to Humboldt or Lyell, geologist-exemplars of a more muscular and rough-hewn scientific archetype, but Becquerel had deduced its existence when the order of his laboratory was upset by a spoiled photographic plate. Except for a fortuitously placed piece of cardboard, Roentgen's first x-ray generating and detecting apparatus was not much different from that of a hundred other nineteenth-century physicists, who passed current through evacuated glass tubes to observe the more mundane cathode rays they emitted. Virtually any physicist from the 1850s onward might have generated x-rays; a few even accidentally made shadow pictures on nearby photographic plates, but only in an age when all the gross phenomena had been catalogued already could subtle things like the x-rays be perceived. This, at least, was the inference made by contemporary discussions of the new energies.

But practicality was even more impressive to the American scientific laity at the turn of the twentieth century than subtlety, and for all that these exquisitely minute vibrations had previously gone unnoticed, properly applied x rays and radioactivity could manifest themselves in remarkably utilitarian ways.[71] Even acknowledging the enormous deficit between the hoped-for uses of x rays and the established uses that had been found for them a year on from their discovery, it was clear that this was not the kind of scientific progress that consisted of adding decimal places to physical constants, or subspecies of frogs to the taxonomic rolls. The flood of news reports about long-carried bullets, needles and other foreign bodies removed by roentgenographic means in that first year is itself sufficient testimony to that fact. It was those kinds of news reports, which came in unprecedented numbers, and appeared in media forms that had never before deigned to cover news of science and industry, that firmly established the new energies as emblems of a new science.

* * *

Both x-rays and radium figure prominently in one of the most significant and widely read works of nonfiction of the early twentieth century. *The Education of Henry Adams*, written in 1907 and published in 1918, won its author a posthumous Pulitzer the following year. The autobiography is a memoir of Adams's rigorously traditional education in the nineteenth century and the sudden and radically different world that science and technology were making manifest at the dawning of the twentieth. Adams regarded x-rays and especially radium as the precipitators of that revolution: covert agents who stealthily staged a sneak attack on the hidebound scientific establishment and laid it to waste. Radium, he wrote, "denied its God," by which he meant the predictable world of the Victorian scientist, and in its maddening inscrutability, "radium happened to radiate something that seemed to explode the scientific magazine."[72] The language Adams uses to describe the rays is invariably that of violence:

> [T]he man of science must have been sleepy indeed who did not jump from his chair like a scared dog when, in 1898, Mme. Curie threw on his desk the metaphysical bomb she called radium.

> . . . Vaguely conscious of the cataclysm, the world sometimes dated it from 1893 [*sic*], by the Roentgen rays, or from 1898, by the Curie's radium; but in 1904, Arthur Balfour [then president of the BAAS] announced on the part of British science that the human race without exception had lived and died in a world of illusion until the last year of the century.[73]

The *Autobiography* was intended as a rejection of the ossifying intellectual traditions of the previous century, and Adams was heartened that the new energies bade well to force new perspectives on the world. A contemporary reviewer saw in Adams's writing "a certain veiled joy over the perturbation among the physicists caused by the disconcerting qualities of the new element."[74] Nevertheless, there is a palpable sense of fear or uncertainty in Adams's tone when he surveyed the inherently chaotic world after 1900, in which "man had translated himself into a new universe which had no common scale of measurement with the old."[75]

Adams was not alone in perceiving matters this way, or in being troubled by them. The havoc that radioactivity had wrought among scientists' pet theories of matter was clearly understood by the press. For all that it was held up as a triumph of modern science, radium was also presented as something almost antiscientific, a deadly poison that had been injected into the comfortable scientific consensus of the nineteenth century. When *Scientific American* admitted that radium suggested there were "more things between heaven and earth than are dreamt of in our chemical philosophy," the general-audience magazine *Suggestion* pounced on it as evidence that "science today is tottering, and tomorrow all our textbooks may be as waste paper."[76] "Radium is like the magic sword of the fairy tales, which conquers everything," columnist William Rittenhouse quoted an unnamed scientist as saying in an article headlined "The Modern Philosopher's Stone."[77] Allusions to alchemy in the infancy of the knowledge of radioactive decay were inevitable, of course, but many went far beyond analogy and into rhetorical territory that suggested that forces other than those familiar to the laboratory were at work. Noting its upheaval on the scientific world, the *Hawkeye* of Burlington, Iowa saluted the "ancient Egyptian priests, the magicians of all ages, the alchemists specifically of the dark ages, for they were, after all, on the right track," and it was hardly alone in making that sort of assessment.[78]

Scientists themselves, particularly those engaged in public lecturing or other forms of popularization, were eager to put the most dramatic face possible on the internal debates that had arisen as a result of the new discoveries. The enthusiasm that the lay public suddenly had for the work of physical scientists was surely personally gratifying, and potentially remunerative on an individual basis. Moreover, as members of the American scientific establishment, which had only recently cohered into vigorous professional societies and established degree programs, they perceived a rare opportunity to tout the value of their own work directly to an attentive public. Having only just achieved an intellectual standpoint meaningfully distinct from other educated elites in the closing years of the nineteenth century, American scientists were anxious to avoid becoming alienated from the laity they had left behind. There was an awareness among scientists at the turn of the century that they were in danger of being walled off by the yellow journalism of the era, which deigned to notice science only when selective exaggeration could make it amusing or spectacular.[79]

Journalism was never yellower than when it treated science at the turn of the century, and the coverage of radium and x-rays was among the most sensational. Yet the many scientists who lectured and gave public demonstrations invariably struck an equally sensational tone, with similar emphasis on the chaos that had resulted from the discovery or radium and x-rays. R. Neil Williams, a Union College physicist, spoke to a group of Schenectady Presbyterians in 1904. The headline in the article that reported it and quoted lengthy passages from it, "Radium Sets At Naught Science," is a fair summary. Williams declared that radium—"mysterious," a "riddle" that had "all the world . . . theorizing and guessing"—had so far bested the "greatest minds of our present day," and put scientists in a "quandary" by "putting the first question mark" to the theory of conservation of energy, in which "all our modern science" is rooted. But this was not an expression of humility on behalf of his professional brethren. Williams's emphasis on the difficulty of the problem allowed him to burnish the credentials of those who were attacking it. He stressed the persistence of Becquerel and the Curies in chasing down the faint emanations from uranium ore, and the physical courage shown by Pierre Curie and William Hammer in braving the inevitable burns from radium handling. The picture he painted was of a scientific establishment that was bloodied but unbroken by the assault that radioactivity had made on their works, and that would shortly gain the upper hand and "break the new servant into the position which will be created for it in the service of mankind."[80]

Such optimism notwithstanding, newspapers delighted in the notion of science set "at naught," and made it a central trope of their coverage. Articles described pitched battles over the nature and meaning of the new energies, conducted via telegram or across the dais at conferences. "Laugh at Prof. Pratt: Eminent Scientists and Physicians Ridicule His Claims," the *Chicago Tribune* reported in 1896, referring to a physician's experiments in using x-rays as a germicidal agent. A column by social critic Max Nordau, syndicated in American newspapers, lashed out at the unseemly glee with which these kinds of controversies were received by the general public, who rejoiced "not in satisfaction over our increased knowledge of nature" but rather "with a malicious joy over the alleged renouncing of the laws which seemed to govern the action of matter. Voices everywhere joyfully proclaimed the overthrow of science. Ignorance believed it was having its revenge on natural knowledge." But he was far angrier with the factions within the scientific community that were moving to abandon the laws of conservation of matter because of radium's unusual properties, and proceeded to paint a lurid picture of hasty "deductive" scientists in a sort of panicky revolt against the sober wisdom of their more cautious "inductive" colleagues.[81]

Not all debates that the papers reported on were quite so uncivil, of course. More typically, a report would have a gathering of scientists stunned into silence by a new finding or theory about the new energies. For example, Rutherford's suggestion that the interior heat of the earth was maintained by the decay of "the mysteriously fascinating element" radium, "startled" the audience at a Royal Institution, who recognized it as the death knell for Lord Kelvin's calculation of the planet's age.[82] The real novelty, from the perspective of readers, was the fact that detailed accounts of such meetings were appearing in the papers in the first place.[83] Yet even in stories that highlighted the inability of scientists and physicians working with the new energies to understand them—stories, that is, explicitly centered around failure—the tone was invariably respectful and positive. A *Washington Times* illustrated story about radium photography demonstrated the print media's dexterity perfectly with its subhead: "Freakish Pictures . . . Baffle Explanation by Those Through Whose Ingenuity They Are Brought About."[84]

This constantly reiterated presentation of the novel radiations as the harbingers of a new scientific revolution, one unfolding in real time in the pages of the daily newspapers, led directly to a distinctly heroic presentation of the scientists and physicians who worked with them. Nordau's complaint notwithstanding, they were generally treated as victorious young Turks who had led their field out of senescence and irrelevance. Ernest Rutherford's accomplishments were summarized this way:

> Science stood at first bewildered by cathode rays, Röntgen rays, X-rays. The immortal Becquerel discovered that potassium uranyl sulphate emitted rays which acted on a photographic plate enveloped in black paper. The Curies analyzed systematically the mineral pitchblende and dumbfounded physicists by isolating radium with its incredible emanations. J.J. Thomson investigated the conductivity of electricity through gases and split the atom into smaller particles. But what did it all mean? The old chemistry was exploded. The physics of the nineteenth century stood discredited. Rutherford explained everything.[85]

The journalist Cleveland Moffett recognized the strength of this tendency even as he lamented it in a 1904 editorial. Crazed by the promises made for radium, the American public had become "like gamblers who reason that the red must turn up soon, and each new message from the laboratory—anybody's laboratory!—finds a cohort of zealous believers." But even this was couched in expressions of awe and reverence toward the Curies, whose work he had personally observed.[86]

The incipient ray-revolution made its leaders famous, but fame also sought out the rays. In the first blush of radiomania, Americans who followed the news of x-rays would have perceived them as nearly the personal province of Thomas Edison and Nikola Tesla, who stood at the front of a small army of local tinkerers and innovators. Edison was, perhaps, the only figure associated with science in 1896 with a fame to rival that which Roentgen's rays were acquiring, and his decision to direct his resources toward developing x-ray technologies was treated in the daily papers as the final validation of the excitement about the rays. Edison's name was mentioned in 89 articles about x-rays during their first year in the public eye, roughly a quarter of the science articles on the rays published by the *Times* of New York and Los Angeles and the *Chicago Daily Tribune*. Tesla, with 31 mentions, had also acquired a reputation as one sufficiently wizardly to marshal the rays. Befitting their iconic status, both men were duly sounded out on radium, too, although neither had any particular interest in the subject. A persistent rumor that Edison had plans to move to Missouri to study "radium caves" there forced him to hire extra stenographers to answer letters on the subject. "He is no more actively interested in the matter any more than any other intelligent man," his exasperated secretary announced.[87]

Tesla and Edison attracted the attention of American journalists because of their locality and accessibility—both had already been embraced as ideally and uniquely American men of science, and neither had developed the shyness with respect to the press that less entrepreneurial American scientists were acquiring. However, nuclear emanations helped make foreign scientists celebrities in the United States, too. The garrulous Ernst Rutherford, in particular, emerged as a favorite subject of journalists, no doubt in part because he had made popularizing the new physics a personal mission and had written accessibly on radioactivity and radiation. Likewise, Frederick Soddy enjoyed the attention of the American press, especially after the publication in 1909 of his popular *Interpretations of Radium* (discussed below). "When it is remembered that [Soddy] is a scientist of international reputation," the *New York Times* rhapsodized, "important and astounding in the extreme is the language which he uses to suggest the revolution in man's existence which will follow the finding of the secret of the artificial transmutation of the elements, a goal now before science as the result of the discovery of radio-activity."[88] Rutherford's famous expostulation to Soddy that "they'll have our heads as alchemists!," if Soddy used words like "transmutation" proved incorrect. Soddy's collaborator and fellow popularizer William Ramsay also rose to fame in the early days of the radium craze.[89]

But even before Pierre Curie's death in 1906, Marie Curie was given pride of place in news accounts as the discoverer of radium, or simply as its "mother," in some accounts. The novelty of a female scientist achieving such success as she did was an element of the narrative that quickly accreted around her in the American press, but the portrait of her that emerged was illuminated by the nature of the substance she had discovered.[90] The energy of the substance, in these accounts, was mapped onto her industriousness, and its perpetual emanation onto her perseverance in working to isolate it.

Her public image on the continent was susceptible to occasional inversions; she had been the subject of a well-contested debate about the role of women in the professions when the Institut de France declined to admit her to membership, and her rumored affair with Paul Langevin in 1911 was inelegantly splashed across the pages of French newspapers. In the American media, however, Mme. Curie was incapable of error, and an even greater moral paragon than model scientist. The efforts made by the press to present Curie in a manner amenable to its readers' tastes is suggestive of the enthusiasm with which her work was greeted. The *New York American* concluded an article on the frugality with which the Curies had lived prior to their discovery with a tribute to her affectionate mothering of her daughter Irene: "So Mme. Curie is not only a scientist, whose name is known throughout the world, but a model wife and mother," and a quiet caution to her "often more pretentious" male colleagues.[91] The epithet "Our Lady of Radium," as *Reader Magazine* had it, was not solely an allusion to the otherworldly gloss frequently given to the substance she had discovered (although it was that), but also a pointed reassurance to its readers that Curie was, indeed, a lady—maternal, charming, and in no way the dreaded "new woman" its readers might imagine a female scientist to be.[92] Of course, it was possible to be more pointed still, as with the assessment of the *Marysville* [Ohio] *Evening Tribune*: "She is an essentially womanly woman. Indeed, her way of combining sweet femininity with the precision of exact science is the marvel of all who listen to her."[93]

The narratives that emerged from the telling and retelling of the scientific community's work with the new energies took the form of morality tales that redounded to the credit of the investigators. Curie is, naturally, the most prominent example here; in newspapers and textbook hagiographies alike, she did not so much isolate radium as give birth to it, labor in a chilly shack standing in rhetorically for labor pains. Edison, too, was industrious. Becquerel and Roentgen were held up as exemplars of the truism that successful men make their own luck: presented with a chance glimpse of the inner workings of nature, they pursued the truth even when it threatened to undermine their understanding of the basics of their field. The fact that both x-rays and radioactivity were subtle phenomena that had gone undetected during a hundred years of sending discharges through evacuated tubes, or several centuries' worth of pitchblende mining and chemical assaying, allowed its laboratory explorers to claim a marvelously subtle perception of their own (although discussion of the rays' *potency* usually took precedence over any appreciation of *subtlety* in most kinds of public discourse about them). A healthy portion of the rhetoric of science in the decades leading up to the twentieth century had to do with its ever-subtler instruments that extended so far into the normally unseen as to allow for the detection of infinitesimal signals from an undersea telegraph cable, or the chemical composition of Arcturus, or the presence of an ethereal medium for light waves in a basement at Western Reserve University. X-rays and radioactivity may not have done any greater damage to the physics of the nineteenth century than Michelson and Morley's experiment, but they did throw it into upheaval, and in the process created a good story. X-rays weren't radio, which followed on from wireless telegraphy, or airplanes that followed on from balloons; they were *sui generis* and *ex machina* all at once, and the surprise and consternation of the physicists became a part of their story. Something of the same attraction toward the bizarre can be seen in the way that relativity was framed for the public in the classic headline "Lights All Askew in the Heavens."[94] It was not altogether unpleasant, and certainly an engaging diversion, for the laity to consider that something was askew with the atoms, too.

The sum effect was to create in the public discourse new kinds of identities for the scientific investigator. If the old stereotype of the scientist had been that of an old wizard, "monopolized by ancient gentlemen with sunken eyes that peered from beneath bushy, grizzled brows," and "who spoke in strange allegorical speeches," then the *San Francisco Call* was pleased in 1901 to introduce its readers to the "clear, cold science" of "San Francisco's Twentieth Century Witch," an x-ray photographer and fluoroscopist named Elizabeth Fleischman. The article's treatment of her is characteristically chauvinist ("A girl wizard is a novelty") but the accompanying pictures show off well the extent of her skills: she produced sharp images of the fine bones of birds and snakes and was sought after by local military hospitals for examinations. Fleischman was, the article concluded, every inch a scientist, one who "can show things that make fairy tales seem commonplace by comparison." Yet she had no background in science, and had taught herself her craft from the do-it-yourself articles that circulated in the wake of Roentgen's announcement. The real novelty was not her sex, but that her chosen field was so receptive to new ideas, so well-suited for anyone with the requisite curiosity and persistence (womanly strengths, the article noted) that anyone might have done as well. Radiation seemed to have opened a few cracks in the wall separating professional scientist or doctor from inquisitive layperson.

Public Demonstrations and Popularizations

Where science was publicly celebrated, in that first decade, x-rays and radium were present. Thomas Edison showed off his work with x-rays at the 1896 Electrical Exposition, where New Yorkers filed through a darkened room to examine the bones of their hands as projected onto Edison's new fluoroscopy screen. Edison, a first-rank celebrity before his recent association with x-rays, personally switched the current for the generating tube on and off. It was not the very first public exhibition of the rays, even in New York, but it was significant for several reasons. Its magnitude was one of them: two thousand people came into direct contact with the Roentgen ray on the first night. Edison's personal presence was another; though newspapers had focused much of their attention with respect to the rays on what the media-savvy and accessible Edison was doing (as opposed to the more circumspect and distant European or American university researchers), this was the first time he had publicly lent his fame to the rays. The reactions of the viewers suggest something of the cultural context for the exhibition: the reporter covering it noted the generally subdued reaction to the appearance of the skeletal images on the screen, the presence of skeptics (including a woman who tested the machine by concealing coins in a glove), and the arguably greater attraction that seeing Edison himself held for some of the viewers.[95]

Edison's performance at the Electrical Exposition was the first of many such demonstrations at large-scale exhibitions. Radium and x-rays quickly became standard fare at the World's Fairs. Theodore Roosevelt's daughter Alice inadvertently gave reporters comic fodder when her x-raying at the 1904 fair in St. Louis revealed no discernible heart.[96] A small tube of refined radium, a novelty among energetic novelties at the same fair, attracted the biggest crowds of any exhibit.[97] Another tiny sample of the substance, yellowish flecks of radium bromide just barely large enough to be visible, caused crowds to swamp the American Museum of Natural History in New York in 1903.[98]

Scientific lecturers of the period often deliberately conflated the marvels of their demonstrations—whether x-rays or voltaic piles or electromagnets—with the language and theatrics of the stage conjuror.[99] Machines that could reliably cast shadows of bones upon a glowing green screen, or compounds that glowed themselves, would themselves have more than adequately suited the sense of wonder that such showmen cultivated. That radiation and radioactivity were commonly (and accurately) understood by their very existence to have overturned the wisdom of the physicists, and chemists of the day added greatly to their mystique and, as noted above, to the belief that they were a tenuous emanation from an altogether weirder dimension of reality. Thus it is not surprising to find evidence, even in the public presentations of the very most unimpeachably "scientific" sorts like Rutherford and Edison, that the new energies were treated as a class apart from more mundane and interpretively settled staples of the public science lecture like static generators or gas cannons. Those who "performed science" for audiences understood the thrill of mysterious forces that defied classification, even as many of them—active researchers like William Hammer, for instance—were at pains to show that a naturalistic understanding of the physical world would emerge all the stronger for the deeper glimpse into the fabric that the new radiations had provided.

In the case of x-rays, the ability to generate them thrust any number of electrical workers or hobbyists, doctors, school science teachers, or ambitious photographers unexpectedly into the spotlight, when they were called upon to demonstrate the rays to a curious public. Professor Edwin J. Freeman of the Winona (Minnesota) Normal School, professionally positioned to reproduce the Roentgen apparatus, traveled to high schools and auditoriums in his immediate vicinity to lecture on the rays, the pictures they produced, and the apparatuses that generated them. His surviving display photographs suggest an easily understood tendency to gratify interest in the bizarre or macabre: in addition to several prints of Minnesotans that reproduce precisely, down to the ring, the iconic hand of Frau Roentgen, his folio included pictures titled "Thigh of a man who was shot out of a well by a blast of dynamite," "Boy's arm—he was born without a hand," and "Big toe was shot off with a shot gun." Shrapnel and shot can be seen in the pictures.

Freeman's images also testify to an experiential aspect to his impromptu career as a public lecturer: several of his display pictures were of the hands of local high school students, taken during his visits and developed into gelatin prints suitable for framing later. A nine-year-old friend of his daughter's, hobbled by an undetected needle in her foot, was given an x-raying by Freeman, too, and that picture as well went into the display file for the edification of the community.[100] The physicist's technique as a roentgenologist left something to be desired—his images were mostly of poor quality even by the standards of 1897, when most of them appear to have been taken, and in some cases the only element clearly discernable is the foreign object in a body. Nevertheless, it appears to have provided him with a gratifying sideline, until he found a more direct professional application for his tinkering with x-rays as a dean at the Northern Institute of Osteopathy in Minneapolis. A photographic tableau of his workspace at the Institute survives, in which an enormous cabinet containing the static generator and tubes sits astride various electrotherapeutic tools and carefully placed x-ray images. The pride that Freeman felt in his equipment is palpable, and gives some sense of the excitement that he and hundreds like him must have felt at being uniquely situated to reveal the extraordinary properties of the "new electric light" to their communities.

Such pioneers found themselves deputized to convey the facts and, usually, the fervor about both the x-rays. The lecture of Professor Bates of Coe College to the members of the Tourist Club of Cedar Rapids, Iowa, was reported on in the local paper and may be taken as exemplary.

> Before beginning his lecture, Professor Bates conducted some interesting experiments. The Tourists went into a dark room to have a view of radium and its wonderful scintillations. Then examples of the X-Ray were shown in several different ways. Looking through the fluoroscope the Tourists saw the shadows of the bones in their hands, wrists, arms, etc. After being amused and instructed in this manner, the tourists and their guests were seated and Professor Bates gave a short talk on the science of matter and energy.[101]

The formula for such affairs would have been obvious to even the most diffident and unlikely public speakers: entertainment in the form of demonstrations and experiments that satisfied the immediate curiosity of the crowds—lectures were invariably reported as being full or overfull—followed by an earnest, if less enthralling, attempt to marry the work of science to the sense of wonder that followed from the demonstrations. *Wonder* was the prevailing mood of the lectures, the adjective of choice for their recounting, and often a word in the titles of the lectures themselves.

But whether the speakers were professional showmen or amateurs pressed into service by virtue of a chance proximity to an x-ray machine or sample of uranium, they owed little fealty to anything other than the immediate entertainment of their audiences, and—to varying degrees—the greater glorification of the scientific enterprise. Consequently, their shows frequently reflected wonder's close emotional cousin, terror. The lectures were early forums in which the hazards of handling radioactive materials or working with x-ray machines could be discussed, often by those with first-hand knowledge. When, for example, in 1904 civil engineer J. R. Scupham was imposed upon by the members of his church to speak on radium, he dwelt on the fact that its rays penetrated more deeply than x-rays, and were consequently more dangerous. He also pointedly rebuffed the notion (commonly bruited about in the press during the radium craze) that there were large, recently discovered lodes of radium waiting to be exploited.[102] Neither theme was exactly barred in the newspapers, but both ran contrary to the portrayal of the new energies that typified media coverage, in which sensationalism more often took an optimistic form.

Radium was a tougher nut than x-rays for the entrepreneurial wonder showman to crack. Its rarity was not an insurmountable problem: except for more quickly causing painful burns, there was no phenomena that concentrated radium could accomplish that weaker solutions could not. The preparations sold at shillings on the gram by London chemists were more than powerful enough to illuminate phosphorescent substances, or discharge a gold leaf electroscope. Nevertheless, some radium showmen found the possession of actual radium to be a needless encumbrance. Henry Tizard, a Fellow of the Royal Society, told of sharing passage on an Australia-bound ship with Ernest Rutherford in 1914, who ultimately yielded to his fellow passengers' demands for a lecture on radium.

> The audience consisted of a few scientific men who knew a great deal about it, others who knew a very little about it, and the other passengers, male and female, who knew nothing about it: but he enthralled us all. He discussed the properties of radium and dwelt upon its extreme rarity and value, and on the danger of keeping it for any length of time near one's skin; and then he said: "Now, in order that you shall all know what radium bromide looks like, I will hand round this tube." The tube was passed rapidly round, handled gingerly, and returned to him safely. I noticed that there was rather a lot of this valuable material in the tube, so I asked Rutherford afterwards what the tube really contained. It was a mixture of common salt and sand.[103]

Rutherford wasn't alone in this minor deception. Radium's gamma rays cause phosphorus to luminesce perpetually, but stage lights provide enough energy to produce the same effect temporarily, and lecturers took advantage of that to spare the expense and trouble of acquiring the genuine article.[104] Its appeal was so obvious that one speaker brought a vial of radium to display during his talks on the Louisiana Purchase, in the apparent (and probably correct) belief that it would guarantee him attention.[105]

No popularizer did more to bring the news of radium to the American public than William Hammer. An engineer who had worked for Thomas Edison, Hammer had established ties with the European physics establishment, including Ernst Rutherford, Frederic Soddy, and the Curies, the last of whom gave him a fraction of a gram of radium in 1902. This extraordinary gift, at a time when refined, concentrated radium was valuable beyond reckoning and present in only a small number of laboratories, put Hammer in a position of considerable influence back home in the United States, as both a researcher and a popularizer. (See Figure 2.4.)

In 1903, Hammer reprinted in book form the text of a lecture he had given in April of that year to the American Institute of Electrical Engineers, titled *Radium, and Other Radioactive Substances.* It was the only mass-market book of its kind on the subject, and was accessible to general audiences in spite of its origin as a formal lecture, if only because electrical engineers would have been little better prepared

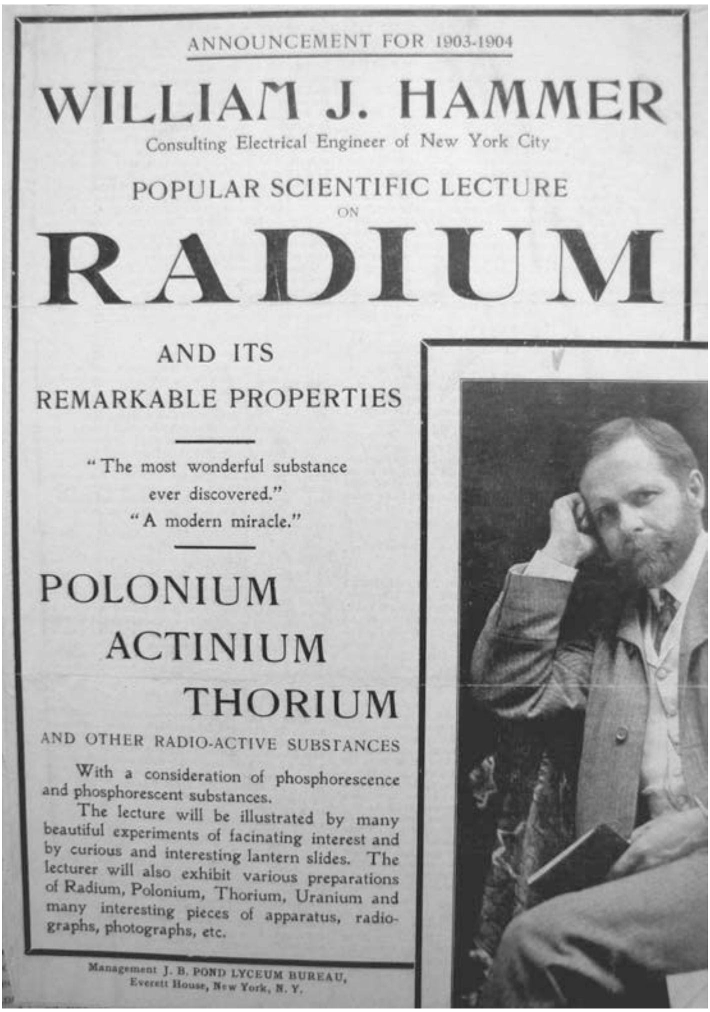

Figure 2.4 A William J. Hammer handbill. William Hammer was one of the chief advocates of radioactivity in the early 1900s through his lectures and books.

to follow a discussion of radiochemistry than a scientifically literate member of the laity. The book made it clear that everyone was starting afresh: even the Curies had only tentative hypotheses about the most fundamental questions posed by radium.

Hammer's book recapitulated virtually every extant radium trope, and created several new ones. On the immediate applications of radium, he gave pride of place to radium-impregnated phosphorescing paint, a substance he was apparently the first to formulate, and which he elsewhere recounted having applied to "gunsights, escutcheons of keyholes, my watch dial and the dial of a large Dutch clock in my home, a small aeroplane, the taps and pulls of my incandescent lamp sockets, push buttons, push pins, small signs, and writing, small plaster figure, my telephone transmitter, poison bottle labels, artificial flowers, etc."[106] But this was just one of many already demonstrated functions for the substance: radioactive elements were inexhaustible heat sources, could be used to identify false gemstones, produced the sensation of light when brought near the temples, discharged electroscopes, gave off a radioactive gas, burned flesh that they were held near to, colored the glass of the vials they were stored in, exposed photographic film, and, in one carefully described experiment, prevented an electric eel from issuing its shock. They seemed to render things in contact with them temporarily radioactive, he told his live audience in a passage that made it into the book: "At the present moment the clothes of every person in this room and all the walls of this room are radioactive by reason of the presence of the nine preparations of radium which I have here this evening." Moreover, Hammer's book reinforced other elements of the popular discourse about radium: that it was almost incalculably precious ("about $2,721,555.90 per pound"), utterly perplexing to scientists, and somewhat sinister in the threat it posed to the human body.

Hammer's colleague Henry Potter, in a July 1903 letter, gave some sense of the rhetorical environment that his relatively sober and restrained book would be born into. "It just occurs to me," he wrote,

> to voice a certain fear that I have had in regard to the popularizing of the latest results in radioactivity. This fear is, that it throws the door wide open for the reintroduction of charms, fetishes, totems, love philters and the whole list of hoodoo and voodoo fakes, which the science of the nineteenth century did so much to exterminate, and which was such a source of profit to the unscrupulous charlatans in the centuries preceding. If a little bottle of radium carried in the vest-pocket will cause a burn, why should not the credulous believe

> that a horse-chestnut will cure rheumatism or a rabbit's hind foot win the America's cup.[107]

Hammer received this point with interest, conceding in a reply that "there are unscrupulous charlatans who are always ready to avail themselves of scientific advances of this nature," and noting that he had "had a very large amount of mail from people of this stamp, cranks, etc."[108] In relation to these cranks, Hammer's own boilerplate lecture, more or less accurately summarized by one newspaper headline as presenting "radium as a Substitute for Gas, Electricity, And as a Positive Cure For Every Disease," was a model of restraint.[109]

A canny self-promoter, Hammer arranged with his publisher for an essentially unlimited supply of author's copies, which he sent by the hundreds to friends, colleagues, and his European contacts. Although the book as published was rough around the edges—it was actually on three unrelated subjects, with only one section on radium—it was popular enough to be reprinted the following year in spite of Hammer's saturation of the market with complimentary copies. Better positioned than most to appreciate the magnitude of the incipient radium craze, he had counted on being first to market as part of his book sales strategy, but the real value for Hammer was the boost that the book's reception gave to his other endeavors, which included a vigorous lecturing schedule. His standard radium lecture commanded $100 in August of 1903, shortly thereafter raised to $200, then $250, and by 1904, up to $500 plus expenses. Hammer's correspondence makes clear that he regarded his speech-making as a means to financial and professional ends. His lawyer and cousin, James Beck, wrote in October 1903 of the lectures that "apart from the merely lucrative side of it, you confirm by every address your high standing as a scientist. I believe the reputation you are thus gaining is even more valuable than your lecture fees, although the latter mean more in immediate comfort. I am inclined to think that you will get some valuable consulting work as a result of your lectures."[110] Beck was prescient; Hammer parlayed his radium fame into a number of other lucrative jobs: writing and editing articles, testifying in patent litigation, and consulting for a radium refining company.[111]

In the meantime, Hammer became something of a clearinghouse for radium popularization in the United States. "You would be surprised," he wrote to a friend, "how many people are writing to me every day about radium, etc. who never think of enclosing a stamp or directed envelope."[112] Some of those requests were not for information about radium but for radium itself: his friend Dayton Miller, an Ohio physicist, was one of several who followed Hammer onto the lecture circuit with radium he lent them.[113] The *American Monthly* wrote to him in September 1903, asking for an article on radium and the Curies pitched appropriately for "an intelligent and congenial smoking-car acquaintance if you wanted to keep him interested on the subject of radium."[114] He obliged them, as he did the editors of the *Encyclopedia Americana*, the *Century Magazine*, and dozens of newspaper interviewers.

All this effort had an effect. "I doubt if there is any country in the world today in which so much intense interest is being taken in your work as in the United States," Hammer wrote to Pierre Curie in the midst of it, "where the scientific and secular press give so much attention to scientific matters and the general public is so well informed."[115] Hammer's assessment of the interest that the Curies' work had aroused was fair, although his regard for the American scientific press, such as it was at the very start of the radium craze, would shortly sour.

Although an engineer by training, Hammer's enthusiasm for the medical applications of radiation—particularly that of radium, and also x-rays and ultraviolet light—presaged and to some degree helped establish the popular discourse on the same subject. Pleading for confidentiality in advance of publishable results, he confided in a 1903 letter to a physician: "I have been experimenting for over a year . . . and I have found that I could make various kinds of medicines, pills, liquids, etc. powerfully radio-active and I have experimented with them upon myself and my family."[116] He was involved in the treatment of Tillie Spitznadel, the little girl who, for all most newspaper readers knew, had been permanently cured of her blindness by radium. Hammer would have been aware of her mother's demurral from the pronouncement of a cure, but he maintained in his private communication months later that he was sure that Spitznadel's vision had improved at least to the point where she could recognize shapes and colors.[117] He shortly became the center of a network of amateur medical experimenters. A 1906 letter from a Mr. Legrand, the friend of a friend, describes the apparently successful application of Hammer's own treatment regimen and radium. Hearing of the Legrand's wounded foot, their mutual friend Sebenius "came to the rescue, and, after having secured some radium from you he produced radio-active water. I injected some into the wounds, steeped a pad of cotton in solution and applied same to outside, and after three days the wounds were completely healed and have never given me the slightest trouble since. Thanks to Mr. Sebenius' forethought and your radium, I am today as hale and hearty as ever."[118] The contemporary reader will see in this account some combination of the placebo effect and confirmation bias, but Legrand's enthusiasm was a leading indicator of the expectations that Americans quickly came to have for medical radium. Hundreds of thousands of devices that "produced radio-active water" in the fashion prescribed by Hammer were eventually sold.

Although Hammer's book on radium was the first popular treatment published in the United States, it was hardly the only such opportunistic exploration of the new energies in the first flush of nuclear culture. The first opportunity that the general public had to purchase a text on the x-rays came in the form of a small book engagingly titled *Something about X-Rays for Everybody* that was rushed into print in June 1896 by Edward Trevert, an author of technical manuals and electrical hobbyist guides. The first half of the book was aimed squarely at the hobbyist audience, and contained detailed instructions on how to construct a working x-ray apparatus. The procedure Trevert described was not technically complex (physicists had been amusing audiences with colored lights from discharge tubes for nearly a century) and the components were inexpensive. (Assuming, that is, they could be found. Crookes tubes had become artificially scarce in some places in 1896, in the rush to replicate Roentgen's work.) The book was an accessible primer that could bridge the gap between the occasional tinkerer and the scientist, and in the second chapter on experiments Trevert made clear that the physics community had no great head start in the race to explore the phenomenon. "With proper care and the necessary apparatus," he noted, "even an amateur may meet with wonderful success."[119]

How many people followed Trevert's instructions cannot be known. At least some, certainly: as the example of home-built radios and community-rigged telephones that occupied American work-sheds a short time later demonstrate, there was a receptiveness to electrical tinkering that followed on naturally from a culture that had long prided itself on mechanical ingenuity and self-reliance. Thomas Edison was the epitome of bench-rule science, and for all that Americans who were reading newspapers knew after mid-February of 1896, he was the world's leading researcher on x-rays. The fact that no one was really an expert in the rays, and that the techniques for producing them or developing their images were both rapidly evolving and manifestly far from perfect, had implications for the entrepreneurially minded: being the first with the capacity to produce the rays in a given locale was a valuable franchise, considering the immediate commercial uses to which they were put.

Moreover, the do-it-yourself approach that framed Trevert's ecumenical booklet would have resonated with an older American style of the laity "doing science," or at least being involved in its production. There had been for centuries an emphasis in the United States on natural history, and latterly on the earth sciences, in which interested amateurs could make significant contributions.[120] By the turn of the century this underlying orientation was being quickly replaced with professionalized, university-centered research programs. The United States' conversion to this model had happened later than it had in Europe, and while the newly minted doctoral programs were sources of intra-professional status for the members of the American contingent of physical scientists, they underscored for amateur enthusiasts the dwindling opportunities for their own contribution.[121] It was to this population that books like *The A B C of the X Rays* (1896) appealed, whose preface dedicated the detailed instructional treatise on how to construct an x-ray rig to those "who desire to add to their stock of general information, and...who wish to pursue for themselves a line of investigation and experiment in the fascinating domain of the mysterious X rays."[122]

For all that radioactivity was alternately construed as rare and dangerous, many of the early popular books described experiments that readers could perform with small amounts of low-grade radium ore. Lord Rayleigh's two hundred page elaboration on radioactivity (already in its second edition by 1906) included a lengthy appendix on 11 different experiments that could be done with a small amount of radium: making autoradiographs from various elements, coloring glass purple through the action of the Becquerel rays, preparing radon, building a spinthariscope, and so forth. The requisite materials, he noted, including radium, were for sale from the advertisers in the back pages of *Nature* for the uncomfortably high price of £10/mg, although inferior preparations would suffice for most purposes.[123] Charles Raffety devoted an entire section of his lay-oriented primer on radioactivity to experiments, and indeed how best to arrange those experiments for the benefit of others in a lecture-demonstration.[124]

For duration and breadth of impact, Frederick Soddy's 1909 *The Interpretation of Radium* stood above all other early popularizations of the rays, and indeed was deeply influential as measured against any book about science in the twentieth century. It received rave reviews, went through four editions in its first 11 years, and encouraged Soddy to write several more treatments on atomic structure and the energies bound up therein.[125] H. G. Wells dedicated his 1914 novel of a civilization-destroying atomic war, *The World Set Free*, to the book itself, while referencing Soddy himself in the novel and occasionally allowing his characters to paraphrase *Interpretation of Radium*. (Soddy repaid the favor, after a fashion, by using the occasion of his 1915 Nobel address to warn of the dangers of an atomic war.)[126] Wells' interest had been caught especially by the comparatively fanciful final chapter of Soddy's work, in which he speculated about the uses to which a slightly more progressed humanity would put the energies of radium and the implicit mastery of transmutation that came with unlocking them. Soddy concluded that the changes would be so great that even a slight miscalculation would plunge the world "back again under the undisputed sway of Nature, to begin once more its upward toilsome journey through the ages." Perhaps the legendary expulsion from Eden was a distant racial memory of just such an event, he speculated.[127]

Most of the book avoided such evocative speculation. Rather, it was a careful, thorough, and occasionally pedantic synthesis of the current state of research into radioactivity. Over and over again, Soddy brought up the fantastical implications of the facts in evidence about radioactivity, many of which had already been bruited about in the press, only to reveal a more mundane reality. The appeal of the book, to judge from reviews, lay in the enormities of the possibilities left unrefuted. As the *New York Times Book Review* put it,

> It is quite impossible within the narrow limits of a newspaper review to do justice to the manner in which Mr. Frederick Soddy has performed his task—to the judgment, restraint, lucidity he has used in building up bit by bit the whole amazing revelation—so that he who reads finds himself at the end sitting firm, and, as it were, accustomed, in face of a set of solid facts which at the beginning he could have regarded only as figments of the wildest fantasy.[128]

For all their ebullient speculations, lecture-demonstrators and popularizers were at least loosely constrained by reality in their presentation of x-rays and radium. They were, at bottom, dealing with real physical phenomena rather than abstract symbols. Other contributors to early American nuclear culture, whose domain was the lexicon and imagery associated with those phenomena, operated under no such restriction. Modernity—or at least novelty—was a staple of the advertising trade at the turn of the century, which had already begun to embrace the rhetoric of science.[129] Unsurprisingly, x-ray and radioactive imagery was as ubiquitous in advertisements as it was in the newspapers. In subsequent years, American nuclear culture would foster many products and services that were (or were at least purported to be) radioactive or employing x-rays in their operation. Initially, though, most ads that featured radiant energy, or its key terms, were for products or services that had nothing whatsoever to do with the emanations themselves.

In a few cases, advertisers were making a subtle reference to the characteristics of the products that bore such names. Curtis' "X-Ray" brand show window lighting might evoke bright, penetrating rays.[130] "Radium silk" had a sort of iridescent sheen to it that suggested phosphorescence. But for the most part, the words that connoted radiant energy—including phonemes like *thoro-*, *radia-*, *Curie-*, *ray-*, *atomo-*, and others—were deployed in commercial pitches and casual language as superlative modifiers and signifiers of modernity. Crandall Cutlery's wares, for example, did not merely have a fine finish, nor even just an *electric* finish, but a *radium electric* finish.[131] Advertisers' adoption of the rhetoric and authoritative tone of science was rooted in the largely validated belief that the perceived objectivity and dispassion of the scientist, properly marshaled on behalf of a given product, would be more convincing than a direct appeal from the interested parties. For a vendor to call its razor blades the finest was to say nothing at all, but to call X-Ray brand razor blades "the finest known to science" was to move the statement at least nominally into the realm of the objective. By the same token was X-Ray Whiskey styled "scientific, substantial, beneficial."[132]

Radiation was unparalleled as a symbol of the scientific establishment, but it also embodied any number of properties that vendors might hope would be associated with their products. Consequently, the lexicon of words associated with radioactive or radiant phenomena found their way into a broad variety of product names and sales pitches. Since the business of the ad copywriter is to know in advance how an audience will react to a pitch, the commercial deployment of rays and ray-talk can give some insight into the connotative status of the phenomena themselves. Some were straightforward enough: the X-Ray Raisin Seeder (which bore the redundant if charmingly direct epithet "The Seeder that Seeds!") was so named because even as early as July 1896 it would have been obvious to any potential purchaser how a raisin seeder with the omniscient powers of an x-ray would be more effective than most. (Perhaps to the dismay of purchasers, the X-Ray Raisin Seeder was a wholly mechanical device.)[133]

Others elaborated on the conceit of what such omniscience would say about their own products, or those of others. Rival sarsaparilla manufacturers traded blows in April and May 1896, and in the process preserved some sense of how the word "x ray" was being casually deployed. "X-RAYS," Hood's Sarsaparilla maintained (that first word in enormous block type), "penetrating opaque bodies reveal what is solid, substantial and indestructible. The searching x-ray of severest public test" validated Hood's sarsaparilla; millions drank it because it had passed "the x-ray of trial and test."[134] Indignantly, Ayer's Sarsaparilla responded with ads snidely granting that "X-Ray Sarsaparilla" was a fine name for "the average sarsaparilla, because X stands for the *unknown quantity*," and "even the X ray throws no light" on why Hood's refused to disclose their recipe. Ayer's, by contrast, was not an x-ray sarsaparilla, but a known quantity.[135]

As trivial as dueling sarsaparilla ads may seem, the fact that x-ray-rhetoric was so quickly adopted, and with such precise intent, reflects the rays' potency as signifiers of the scientific. It was one thing to have a pure and unadulterated product, but quite another for it to have been submitted to "the X Ray of analysis," even if the product in question was a soft drink. The frequency of its use shows the power of this sort of invocation: Paul Frame has collected examples of "X-Ray" soap (1898), headache tablets (1899), and stove polish (1902), among others, including the entire family of products made by the "X-Ray Ins. Laboratories, Inc.," which included x-ray-branded insecticides, polishes, disinfectants, and floor wax.[136] To this list, radiologist and historian Edwin S. Gerson has added condoms, antiseptic ointment, liniment, dry cells, lamp reflectors, coffee grinders, lemon squeezers, and chicken incubators, among other things.[137] None of these products had or claimed any connection with the properties of the rays; they simply borrowed against the rays' cultural capital. Radium, which in later years would be incorporated into various products as an (alleged) actual ingredient, was the subject of even more rhetorical "borrowing." Stove enamel, butter, cigars, condoms, beer, clippers, playing cards, bootblack, razor blades, and laundry starch all bore the word "radium" in their trade names, solely for the purpose of arresting the attention of a fascinated public. The cumulative effect of the barrage of ray-themed brands and sales pitches was to create a mercantile proxy for parts of the culture where the actual rays did not penetrate.

* * *

Value judgments about the new energies were even more effectively conveyed in fiction. Occasionally, American newspapers published unmarked fiction in the guise of straight reporting, either as a means of editiorializing or simply for the sake of entertainment. The air of unreality about x-rays and radium made them obvious choices for this kind of whitewash story: for example, a superstitious man who wanted to use x-rays to help him propose marriage, or of how x-ray portraiture had revealed the minds of prominent politicians.[138] On other topics, the intent of such pseudo-reportage was not simply to amuse, but to make a point without being unduly encumbered by burdensome facts. With respect to radium and x-rays, there was already enough confusion about the difference between what was plausible and impossible that some readers were fooled. It isn't clear, for example, which specific detail in a 1904 article describing the "radium roulette" that had piqued the interest of jaded Manhattanites would have been enough of a wink. Its description of the light from the radioactive roulette ball and phosphorescent chips is more fanciful than plausible, and the sangfroid of the gamblers in the face of an encounter with radium (they play in "ghastly silence," to heighten the eerie mood) is incongruous with other contemporary accounts of museums being mobbed to catch a glimpse of un-glowing radium bromide, yet readers were fascinated by the substance precisely because it was so difficult to tell fact from fiction.[139]

Of course, not all radiant fiction went unlabeled. The new energies proved as useful to writers as they had to sermonizers and salesmen, as both metaphor and subject. The short story "Uncle Jimmie and the X-Ray Doctor," written by one Mrs. L. H. Harris for the *Independent* in 1903, offers a glimpse of how information about x-rays was being disseminated and digested. Uncle Jimmie, a stock hillbilly character and the narrator, has discovered a white patch of skin he is told may be leucoderma ("luker-dammer"). Fearing it is contagious, he travels to Atlanta to see a doctor who has "some sort of lightenin' machine fer takin' off cancers, bonefelons, warts, and had even drawed a bug outen a little gal's year with hit." Jimmie is frightened at the prospect of being rayed: he believes he will be struck with a lightning bolt from the machine, and further, "the room was dark, an' I felt creepy like I was bein' conjured." He steels himself and tells the doctor to proceed, only to find out that the x-ray examination and treatment has been underway for ten minutes already. The doctor cannot convince Jimmie that the dim light from the tube is enough to make his bones visible, and so steps in front of the fluoroscopy screen himself, casting a shadow of his skull. Jimmie is terrified and runs out of the office, hiding in a train depot closet until he can leave the city altogether. A week later, his skin clears up, and he sends "the conjurer" a quarter in payment, but swears he'll never dabble in such witchcraft again, as "the Bible's ag'in sech doin's."[140]

The *Independent* was a relatively highbrow journal, and Harris's story was on one level the broad lampoon of ignorant hicks that it appears to be, with the ultramodern and scientific x-rays serving as a point of contrast against the illiterate and superstitious stagecoach driver. Nevertheless, it captures neatly the mindset of many patients going in for their first x-raying, regardless of class. It was not uncommon for patients to confuse the static sparks of the generator for the ray itself, or to be upset by the noise of the machine, or to experience revulsion at the image of their bones. The language of witchcraft and wizardry that Uncle Jimmie uses is no more outlandish than a typical contemporary Sunday section article about x-rays. However uncharitably Harris treated her protagonist, she spoke authoritatively about the state of the discourse with respect to the Roentgen ray, and used the buffoonish and reactionary Jimmie to convey an editorial opinion about it: be not afraid.

Radiomania overlapped with the first full flowering of proper science fiction in the United States. Garrett P. Serviss's 1898 novel *Edison's Conquest of Mars*, intended as a sequel to Wells's *War of the Worlds,* was one of the first of many such novels to feature exotic rays. Having been brought low by terrestrial microbes, the Martian invaders flee, doing almost as much damage in the process as they had by their attack. The surviving remnants of humanity despairs—

> But there was a gleam of hope of which the general public as yet knew nothing. It was due to a few dauntless men of science, conspicuous among whom were Lord Kelvin, the great English savant; Herr Roentgen, the discoverer of the famous X ray, and especially Thomas A. Edison.[141]

Had the book been written a few years later, the Curies and Becquerel surely would have joined the list of surviving scientists. The fictional Edison reverse engineers the Martian rays from some wrecked machinery, and immediately and effortlessly adapts it into a propulsive mechanism for a spacecraft. Mars is duly conquered with its own rays, largely because Edison's inventive faculties allow him to improve upon the Martians' ray design, which Serviss makes the product of a sort of evolved instinct rather than technological faculty.

Edison's Conquest of Mars is a cartoonish work by the standards of Serviss's later career as a fiction author and sometime-science journalist, but it contains in embryonic form many ray tropes that would later thrive in the pulp era of science fiction. Serviss used the exotic rays for everything not already achievable by mundane science—to heat, to propel, to deflect, to disintegrate. Exquisitely simple in principle—Serviss devotes only a few lines to any sort of mechanism for the rays, beyond likening them to x-rays and noting that their "vibrations" disrupt the molecular integrity of matter—they can be harnessed only by the wisest of men, and even then only scarcely controlled.

Radiation Becomes a Physical Reality for Americans

By the time that radioactivity entered the conversation in 1903, the high possibility of radium fraud was easily understood. "All that glitters is not gold, and all that is shouted about is not radium," the *Los Angeles Times* warned. "Keep a weather eye out for the sharp that wants to sell you radium rays guaranteed to cure all diseases that flesh is heir to at $2.50 a bottle."[142] Consumers knew, however, that radium was preposterously rare, and this severely limited fraudsters' ability to sell ersatz radioactive cures during the initial craze. A much more common radium swindle involved selling shares in fraudulent mining outfits, trading on its astronomical value but geographic vagueness in the mind of the "radium-mad" public.[143]

In part because of this kind of opportunistic hoaxing, and more often because of actual prospecting (albeit with dubiously reliable results), reports began to circulate of radium's appearance in many locations across the United States. For a brief period at the start of the radium craze, it was essentially placeless in print accounts, described only in the contexts of laboratories. Spa operators, in particular, made a point of having the local waters tested for radioactivity: as most groundwater is to some extent measurably radioactive, many places on the map instantly acquired a radioactive connotation.

But there was also an element of the gold rush, too, that accounted for much of the place-specific journalistic interest in radium. "No longer may Connecticut properly be called the 'Nutmeg State,'" the *New Haven Register* optimistically opined in 1903, with the discovery of a vein of radium-rich ore that, properly exploited, could "pay the national debts of England and America."[144] Word reached New York on two successive days of radium near either Canadian coast: an unnamed British Columbian plot on May 8, 1904, and in a mica mine in Quebec on May 9.[145] The years 1903 and 1904 also saw claims staked for radium in Wyoming, Utah, Colorado, Oklahoma, and Kansas.[146] North Carolinians hoping for a radium boom in their own state had to be content with the possibility of a rich vein of thorium ore, which had "similar radioactive effects," but, lamentably, was "one-millionth of the cost," and so perhaps not a gateway to riches.[147]

X-rays, too, moved quickly out of the laboratory and into contact with a fascinated public. The author of *The New Photography*, a book hastily put into print before the end of 1896, noted that "among the general public it was supposed that it was a new source of light producing light by which a photograph of anybody, or even of their skeleton, could be taken by the ubiquitous amateur through a flight of stairs and a steel door."[148] As much is reflected in the archetypal 1896 x-ray cartoon from *Life*, in which a portrait photographer tells his bucolic subject, "Look pleasant, please!" while the image produced is of a grinning death-head complete with scythe. (See Figure 2.5.)

Figure 2.5 "Look Pleasant, Please." This cartoon appeared in *Life Magazine* in February, 1896. The rays were funny, but still faintly ominous.

Although the reality was rather more prosaic, a genuine interest in x-ray portraiture flared up in the wake of Roentgen's announcement. Because professional photographers were already experienced in the tricky process of developing photographic plates, they were well positioned to capitalize on the x-ray craze. Although most limited their services exclusively to the medical profession (in the process, forming the bulk of the first generation of radiologists), some also tried their hand at artistic x-ray portraiture. Either way, it was an easy business to enter: equipment manufacturers courted entrepreneurial photographers just as they did medical doctors, with one early entrant into the market recommending to "physicians, professors, photographers and students" an apparatus "complete in handsome case, including coil, condenser, two sets of tubes, battery, etc., for the price of $15" including delivery charges.[149] The simplicity and the affordability of these kit machines encouraged hobbyist and semiprofessional use, and helped bring virtually every American within easy reach of the rays before the end of the nineteenth century.

"The woman who has a good collection of photographs nowadays is pretty sure to have herself, one way or another, taken by X rays," the *New York Times* felt free to aver in May 1898.[150] In January of that year, the National Academy of Design in New York, sponsored by Kodak, exhibited a selection of x-ray pictures alongside prizewinning regular photographs.[151] Those further afield could purchase books of x-ray photographs, or take advantage of offers like that made by the youth magazine *The Great Round World*, which would deliver thirty-nine roentgenographs mounted on card stock for 50 cents.[152] In later decades, though, the appeal of x-ray art and portraiture diminished considerably, either because of concerns about unnecessary exposure to the rays, or—far more probably—the novelty of the shadows-and-bones aesthetic had worn off.

* * *

Medical encounters accounted for most Americans' first contact with x-rays, however. For anyone with an electric current source and an evacuated tube, x-rays were trivially easy to generate, and some early clinical x-ray machines were assembled from scratch. However, most early-adopting physicians and hospitals purchased readymade machines, or adapted their existing electrotherapeutic cabinets to work with commercial gas tubes. This was a remunerative sideline, but also an expensive one: prices at the turn of the century for even a bare-bones apparatus rarely fell below $500 when freight and the necessary accessories were factored in, to say nothing of the added cost of electrification or a generator, the construction of lightproof examining and developing rooms, and the consumable tubes, glass plates and chemicals needed to produce an image. Small wonder, then, that many physicians were pleased to see in their patients an appropriate awe, or even fear, of the looming cabinet with its imposing array of switches and rheostats and accessories. It validated at a glance the doctor's credentials as a purveyor of the new scientific medicine—at least, when everything worked as expected. For their part, physicians tended to regard the addition of an x-ray apparatus as a momentous occasion for their practice, both in terms of its impact on patient care and on the practice's finances. Referring to a static generator and tubes that made him the first local doctor to use x-rays, Texas physician Charles H. McCollum was pleased that "when my newly purchased appliances had been added to the rather modern equipment I already had, my office became a sort of show place of the town."[153] X-ray machines were usually given pride of place in the examination rooms, arrayed in such a way as to draw attention to themselves even when not in use.[154]

Physicians tended to learn their new trade on the job. Many who began offering x-ray services in the years immediately following their discovery were complete novices with respect to the equipment that produced them, and little if any grasp of the physics involved. In this respect, the first generation of "x-ray doctors" had—with notable exceptions—far more in common with the sensibilities of their patients with respect to Roentgen's rays than they did with physicists of their day or the professionalized radiologists who would ultimately supersede them. An early textbook aimed at doctors who were adding x-rays to their practice advertised itself this way: "This book is intended for the general practitioner who, having purchased an electrical outfit and desiring to make use of it, finds himself hopelessly at sea, not only in applying his various rays and currents, but in the use and care of the machine itself."[155]

Those "better educated" patients, for their part, brought their own rich and varied understandings of x-rays to the experience of being x-rayed in the gas tube era. Their attitudes regarding the rays ran the gamut from horror to unseemly interest, and the effect of that unusually strong interest can be seen in the evolution of the machines themselves and the way they were used. Because nervous reactions could spoil both images and profits, doctors were especially inclined to note the reactions of nervous patients. Monell wrote in a 1902 textbook of a 15-year-old girl with an injured shoulder who, when asked to stand for a fluoroscopic examination, "exhibited the greatest terror. . . . She declared that she 'knew it would burn her up and hurt awfully,'" and even after seeing a nurse undergo the procedure was still "so nervous and alarmed that she was almost in hysterics." Monell blamed newspapers as the source of her fears, but word of mouth from burned patients played a role in spreading these ideas, too.[156] So many were burned in the 1890s, one practitioner recalled, that patients often entered the clinic "gun shy," and that "almost a decade passed before the average citizen failed to talk 'burns' when x-ray examination was suggested."[157]

At the other extreme were patients whose impressions of the healing potential of the "new electric light" were such that they insisted on its use regardless of their actual complaints, or lack thereof. "Through lurid stories in the daily press and in the pseudo-scientific sections of the Sunday supplements," a memoirist physician named Ernest Smith wrote, "many people have been led to believe that the roentgen ray can reveal almost anything." Some patients, he added, "walk into the office of a general practitioner and expect to receive a five-minute 'tell-all' report on his physical condition by means of the roentgen ray."[158] It was because of this class of patients that doctors like R. M. Burlingame of Hendricks, Minnesota felt obliged to add the boldfaced caveat "when necessary" to their advertisement of x-ray services.[159] A physician wrote in 1898 of being inundated with blind would-be patients—"poor, unduly misled individuals who arrive at our office and demand treatment with the x-rays, feeling assured that they may be made to see at once."[160] He, too, blamed the newspapers for unduly raising the public's expectations.

Enthusiastic patients often mistook diagnostic x-rays for therapy, when they understood the difference at all. Eli Friedman wrote of a panicked mother whose infant son had been diagnosed via x-rays with an enlarged thymus by three other doctors before she came to him late one night, begging him for another "x-ray treatment."[161] So common was the expectation that x-irradiation could be a panacea that even patients who had steeled themselves against psychosomatic effects believed they saw improvement as a result of contact with the rays. One woman wrote to thank Dr. M. H. Richardson for the "splendid effect" of his diagnostic x-rays of her injured foot, adding that "my family think it is all imagination, but that is impossible, because all that I expected from the rays was what you might discern." Richardson, in relating this to his local medical journal, acidly noted that patients also sometimes attributed cures to thermometry.[162]

This diversity of patients' initial reactions reflects the similar breadth of information available about the x-rays that had been available from the moment of their announcement. Even relatively neutral media reports, ostensibly on the same subject, carried widely divergent tones. When readers of the *New York Times* in 1908 heard about a new kind of tube that "robs the X-Ray of its terrors" such that patients "need no longer fear the painful, disfiguring, and sometimes fatal burns which have hitherto accompanied its employment," *Los Angeles Times* readers instead saw an encomium to ten years of "marvelous results" in radiological experimentation marred only by a handful of "regrettable accidents."[163] Each patient's expectations were the result of their idiosyncratic path through the forest of other people's perceptions of the rays. Between the testimonials of friends and family who had been x-rayed, sensationalist articles in magazines and newspapers, lecture-demonstrators and wonder showmen, and all the other occult avenues through which information about the rays might be passed, a patient might have formed almost *any* impression.

Whatever notions that patients might have brought into the examination room, the experience of coming physically into contact with the x-rays was dramatic in its own right. "The psychology of roentgenology would make for an interesting study," wrote Arthur Dunn in the *Journal of Roentgenology* in 1919. "The dim lights and strange glares in a black darkness, the whir of machinery, the assemblage of unusual objects, all tend to arouse the dormant sense of the supernatural."[164] Even a simple diagnostic x-ray, on a perfectly functioning machine, to confirm a straightforward diagnosis of a minor complaint required the use of an apparatus that assaulted the senses with unfamiliar and vivid sights, sounds, and smells. The mere presence of the machine itself, usually larger and evidently more expensive and complex than anything else in the examining suite, made impressions on patients whose previous visits to the same doctor might have involved no procedure more ostentatiously significant of a commitment to scientific medicine than the meticulous recording of body temperature. (Dunn accused his professional brethren of being "likely to trade too much on this asset.") (See Figure 2.6.)

The electric discharges given off by the machine were the most striking element for patients. "The psychic effect of a red-hot four-inch spark was rather torrid," deadpanned one medical memoirist of his turn-of-the-century machine. "You had a convert right then and there; incidentally the convert had a blister, but blisters didn't count."[165] Not all the converts were to the side of radiomania, though. Even

Figure 2.6 The Aristo 1907 model x-ray machine. Early x-ray cabinets were more reliable for the impression they made on the patient than for their day-to-day operation

when patients had been acculturated to electricity, they nevertheless tended to harbor a healthy fear of sparks. Given the rays' early visual iconography, reified by a thousand newspaper cartoons in which a subject was often rendered literally transparent by stylized lightning bolts, it was possible for patients to suspect that the sparks *were* the rays.[166] Nor were fears of coming in contact with the sparks entirely unfounded: patients and doctors alike were routinely shocked when the spark discharge went awry, or when they accidentally touched exposed high-tension wires or ungrounded parts of the machine. The shocks themselves were not usually dangerous (though fatalities were reported) but were certainly unpleasant enough to make an impression on those who received one.[167] They also presented a fire hazard, especially in the presence of ether.[168] "No one could really be considered a radiologist until he had received at least one good shock," one physician reminisced, although shocked patients were not necessarily so philosophical.[169] Even if patients turned their eyes away from the spark, the noise of it remained. The manufacturer of a purportedly noiseless apparatus took care to remind doctors that such noises were "very violent and irritating and *absolutely fatal* to the peace of mind of a nervously constituted patient."[170]

Some sense of the prevalence of these fears can be gathered from the frequency with which early x-ray adopters spoke of ways to assuage—or circumvent—these anxieties in patients. Kassabian, participating in a discussion at the 1909 meeting of the American Roentgen Ray Society, recommended administering anesthetics before an anxious patient even entered the room, and only then gradually acclimating the sedated patient to the spark of the machine, before finally beginning the examination. His colleague Percy Brown demurred, advocating for "more psychological method[s] of producing quiet," on the grounds that anesthesia could produce involuntary spasms in a patient that were just as bad as nervous shaking. A third commenter preferred to fight fear with fear: faced with frightened children, George Johnston said, "I blow a very shrill whistle with considerable force. The noise petrifies the child long enough so that I can make a very good exposure."[171]

Once patients were before the machine itself, the part of the body to be exposed was brought within a few inches of the tube. Tubes were so fragile that any agitation might cause them to implode, as they frequently and spectacularly did. This was alarming enough when it happened during the warming-up phase, but when it happened during an actual exposure, the patient might be showered in shattered or even molten glass.[172] Because there was so little substance to the glass (so as not to absorb the rays generated within), the injuries this might cause were minor, as Henry Pancoast emphasized in reporting two of his own brushes with imploding tubes, but the noise and surprise of the experience were considerable.[173]

The fragility of the tubes, and the fact that they were tethered to the sizable transformers or static generators that powered them, meant that they were largely immobile in early apparatuses. Consequently, patients, no matter how injured, were forced to conform to them. Bodies might be slung headfirst over chairs, or strapped to boards and suspended by chains above the machine.[174] In fluoroscopic examination, the doctor, too, had to adopt contorted poses. For fluoroscopy of the lungs, for instance, a doctor might sit in a chair beneath a specially tilted table, looking up through the patient's chest toward the tube placed above them both.[175] More often, though, specialized equipment was lacking and both doctor and patient made do as best they could. Even patients not in immediate physical distress found it difficult to remain still in the extraordinary poses necessary to get the proper angle, and for the length of time necessary to get the proper exposure (often as long as ten minutes, and occasionally up to an hour).[176]

Techniques for immobilizing patients before the tube ranged from chloroform to sandbags to the elaborate apparatus devised by Percy Brown of Boston for x-rays of the head.[177] Noting that the pain patients sometimes complained of during an x-raying probably came from the muscular stress of having to hold a position for lengthy exposures, Brown built an adjustable wheeled chair with head restraints that was intended to accommodate an x-ray source and photographic plates while relieving the subject of the responsibility for holding himself still: "He, therefore, resigns himself to the mental comfort of this assurance" and was spared both pain and a blurry exposure.[178] Some parts of the body simply defied imaging or therapeutic irradiation except with the addition of special accoutrements. The Sweet eye localizer, for example, consisted of metal prongs attached to a band strapped around the head, which were inserted under the eyelid and pressed, by a screw mechanism, against the surface of the eye itself. The purpose was to aid in exposure of ocular x-rays and to serve as a point of reference; the effect on the patient can be imagined. One of the first dental x-rays required packing the mouth with so much gutta percha and film that an anesthetic cocaine spray was needed to prevent the subject from gagging.[179]

When the patient was arranged and the apparatus was ready, the patient of the early gas tube era beheld an eerie tableau of light and shadow. Because fluoroscopy required doctors' eyes to be sensitive to very faintly glowing images, examination rooms were windowless and the procedure took place in near-darkness. Some procedures required the patient to hold up a fluoroscopic screen against their chests, which allowed the dim phosphorescent glow to fill the room. The electrified evacuated tube also glowed, and these visible light rays were occasionally mistaken for the x-rays themselves by patients.

The weirdness of these new sensations extended to patients' sense of smell. The sparks flying across the terminals of static generators created a great deal of ozone that was not only unfamiliar to many people in the days before widespread electrification, but also irritated their eyes and lungs. When struck by x-rays, wires in the machine itself would also emit ozone and nitrous oxide, and "fluorese [*sic*] like a cat's tail," in the words of a North Dakota physician, suggesting yet another unexpected phenomenon to command the patient's attention.[180] Gasoline generators added to the odors in the windowless examination rooms. If induction coils were used rather than static generators, the smell of ozone was supplemented with that of hot oil from the insulating bath that those coils required. The miasma that built up in x-ray rooms was not merely unpleasant; a 1919 textbook deemed an exhaust fan "absolutely essential" because "[t]he ozone which is liberated in the room during the use of the high tension currents which are necessary in deep therapy becomes poisonous to the patients and makes them very sick."[181]

Even the sense of taste could be a part of the immersive and affective experience of the early x-ray. Fluoroscopy of the gastrointestinal tract required the consumption of food or liquids that had been impregnated with a radiopaque substance like barium or bismuth. Perhaps the only dramatic sensory element of the radiological experience that has never been muted in some way by technological or methodological refinement, barium drinks were prominent among the unlooked-for indignities that patients suffered in order to undergo diagnosis by the icon of scientific medicine. The ominously restrained advertising slogan of the Buck Barium Meal, "It Does Not Nauseate the Patient," gives some sense of the best that doctors could hope for.[182] The worst-case scenario, even for this ancillary procedure, was grim: druggists sometimes supplied barium sulph*ide*, a poison, when doctors requested the barium sulph*ate* used to make opaque meals.[183] Even the correct compound could occasionally react with food in such a way as to create toxic salts.[184] Bismuth, too, was toxic; iron oxides were tried, but they discolored food so badly that patients were disgusted by the resulting meal even before it was ingested. "Finicky" patients might swallow the "thoroughly unobjectionable" zirconium oxide, a roentgenologist suggested in 1910, but it was not widely adopted.[185]

The sum effect of just a few of these dramatic manifestations of the x-raying process was sometimes enough to overwhelm patients. Henry Pleasants, a general practitioner, gave a fairly vivid sense of the impression that even a simple fluoroscoping could make:

> It was a frightfully hot day, and the x-ray laboratory was like the inside of a furnace. All cracks had been closed so that no light could possibly

> enter. . . . The patient was stood upright before the "fluoroscopic screen" and told to drink the nauseous mess [a barium drink]. . . . Just as things began happening, I felt something wet and cold strike the top of my head in the dark. At the same instant, the patient's knees buckled forward and he collapsed in a dead faint on my shoulder, pouring the rest of the meal down my back.[186]

Nothing about the procedure Pleasants describes was unusual, nor is this kind of reminiscence atypical for x-ray-employing physicians of the early decades.

Indeed, dealing with this sort of anxious patient was a source of constant concern to physicians and radiologists, who discussed various tactics for defusing those worries at conferences and in their disciplinary journals. The problem was worsened by a gradual change in technique brought about by their recognition of the cumulative effect of chronic irradiation, and the harm it was doing to physicians. Forced to balance the suddenly urgent need to protect themselves from exposure with the need to reassure patients that the process was safe, doctors began wearing protective garments. The first such suit was a thick rubberized leather smock, with elbow-length gloves and a bucket-shaped helmet with two smoked-glass inserts for eyeholes.[187] Monstrous in appearance, it had the benefit of thoroughness, but clearly would not put at ease the sort of patient who had heard of x-ray burns and had to be cajoled into the process in the first place.

Notwithstanding the rhetoric of voyeurism and violation that occasionally attended early public discourse about the rays, some patients entered the examination room hopeful that the new technology would preserve their modesty by sparing them the need to fully undress in front of a doctor. This was not an entirely vain hope: in March 1896, Dr. Edward Parker Davis reported with surprise that a pregnant patient of his was not only untroubled by the imposing electrical apparatus that he proposed to use in an examination of the fetus, but that she much preferred the use of a machine which "requires no exposure of the patient, no vaginal manipulation, and puts her to no essential discomfort."[188] Similarly, patients frequently sought out x-ray treatment in the hope that it would render surgery unnecessary. First-generation radiologist Albert Soiland cited breast cancer sufferers' willingness to submit to any degree of irradiation—from any source, no matter how disreputable—rather than face the "mutilation" of a mastectomy.[189] This was in keeping with the generally credulous and miracle-themed coverage of the rays' medical applications in their first two decades.

In therapeutic radiology, however, where specificity of dosage and precision of application was an important consideration, and any bodily orifice might be exploited to help localize the irradiation, patients might have wondered whether x-rays were really any less invasive than surgery. By 1907, a Toledo physician had developed a procedure for the treatment of uterine cancer that involved a standard gas tube being partially inserted into the vagina while the patient, under local anesthesia to ensure muscular relaxation, knelt on a couch.[190] Though an unusually graphic inversion of patients' hopes that x-ray treatment would be less immodest or invasive than traditional methods, it was hardly the only one: special tubes for insertion into the vagina, throat, and rectum were subsequently manufactured. Even relatively simple diagnostic imaging of the urinary system required the subject to undergo a day's fasting and an enema or purgative.[191]

Therapeutic radiology also brought with it the possibility—and, early on, the certainty—of a burn, which manifested several days after the treatment. Many physicians, of course, knew what x-ray erythema felt like, even if only from a single acute overexposure during fluoroscopy. At the annual meeting of the American Roentgen Ray Society in 1904, John Pitkin put it this way:

> For a description of the pain and suffering [of an x-ray burn], *hyperaesthesia paresthesia*, no language sacred or profane is adequate. The sting of the honey-bees or the passage of a renal calculus is painful enough, but they are comparative pleasures, because being paroxysmal they have a time limitation.
>
> Extreme tenderness to the slightest touch. Hot and cold waves and flashes, warmth, tingling, pricking, throbbing, stinging, crawling, boring and burning sensations, as if the parts were on fire and contained bugs, and other living things. . . . All forms of radiant energy, light, heat, magnetism, ultra-violet rays, etc., increase the suffering.[192]

But because the burn so often accompanied an apparent cure of the patient's complaint, it was treated as a benchmark of adequate exposure in therapeutic radiology. "I make it a point in every case to produce a 'burn,'" averred Dr. H. W. Wright of Ottawa, Kansas—not in a medical journal, but as a selling point in an advertisement for the company whose apparatus made it so easy to do so.[193] The pressing question for doctors was not whether to burn, but how to manage patients' fears. "I make it a point of telling everybody who is exposed to the X-ray, whether for purposes of making an X-ray picture, a fluoroscopic examination or radio-therapeutic treatment, that I may produce a burn or dermatitis," Emil Grubbe told his colleagues at a professional conference in 1902. "If you do that you will save yourself much trouble and it will do you no harm."[194] His colleague Wilbur Hamilton went one step further: furious that sensationalist coverage in the papers had put the fear of burns into the heads of "nine out of ten patients," he found that he could only "set their minds at ease by assuring them that we will not be satisfied *until we have produced just that result*."[195]

This grim assurance carried weight with patients precisely because there was no substitute for the x-ray's apparently miraculous ability to reduce tumors, blanch scar tissue or keloid lesions, treat acne and warts, or otherwise make comparatively normal bodies that had been disfigured by growths of some sort. When irradiation causes a tumor or lesion to undergo a change in size or external presentation, it does not necessarily improve the overall prognosis. Nevertheless, the stark difference in appearance that x-irradiation could effect in such cases, combined with the fact that radiation therapy provided an alternative to surgery, made such an impression on patients that, doctors complained, they occasionally failed to complete the course of treatment. Others demanded more: dentist Weston Price wrote in 1904 of his amazement at the lengths an elderly patient would go to in order to obtain more of the treatments he was giving her for a periodontal disease.[196] Physicians, too, were amazed at the relief that the rays could offer otherwise irremediable disorders, especially lupus, and lesions or tumors on the face. Radiology journals and textbooks were shot through with before-and-after photos, and it was a mark of professional pride for pioneer radiologists that they could offer some hope to patients that surgeons could not help.

Conclusions

The ineradicable weirdness of an x-ray image, or the raw impudence of a metal that slowly burned, seemingly forever, without regard for scientific law: these were things that would have arrested the attention of the American public no matter what their larger significance to scientific understanding. The fact that their weirdness extended to and altered the human body, for better and for worse, made them all the more compelling. The new energies were, in every sense of the term, taken personally.

Radiation also acted on the tissue of the American scientific community, rendering it transparent to the public view in ways it never had been before, and simultaneously withering it and strengthening it. The disruption in the status quo that the laity perceived was real enough, of course. Speaking to a private audience of Yale Medical School alumni, the physician Robert Abbe made a startling admission that on the subject of radium, the medical community was to some extent taking its cue from the "audacious" speculations in the press. "Physicians and surgeons are driven ahead of their work by excited newspapers and by advertising firms who have wares to sell, and are forced to keep abreast of the times, finding that the newspapers are occasionally ahead of them. Stimulating as this is, it spurs the physician and surgeon to work out his problems."[197] Professional dignity would have kept him from ever saying so to his own patients, but it is clear that the laity felt that the playing field had, at least temporarily, been leveled. From the vantage point of the first decade of the twentieth century, it was plain enough to nonscientist Americans that physicists' laws had been undone by the new rays, and that physicians were making up their radiological practices and protocols as they went along. Indeed, radium had made it "Fashionable Now To Be Scientific," the *New York Herald* felt safe to say in December 1903, and that lectures on the subject were "the rage at afternoon teas."[198] Ambrose Bierce's satirical *Devil's Dictionary* had its say, too, defining radium as "a mineral that gives off heat and stimulates the organ that a scientist is a fool with."[199] Little wonder that the general public felt entitled to "fool" with the grand mysteries of x-rays and radioactivity, too.

It soon became apparent that speculation could be taken too far to be sustainable. Roentgen rays and radium emerged from their time in the spotlight as celebrities, and that star turn had brought with it great expectations for what was to follow. These were not uniformly positive; for all the excitement, the reviews had been somewhat mixed. Universal attention had not brought universal acceptance of the rays' potential, and their prima facie implausibility engendered skepticism, too. The Chamley Cancer Institute, a naturopathic franchise operating several hospitals in 1905, put the legend "NO X-RAY OR OTHER SWINDLE" alongside the more traditional medical bugbears, like surgery or payment in advance, that it promised to avoid.[200] This was not simply casual slander of allopaths and their devices; it reflected the fact that hundreds of overlapping and increasingly fantastic claims made on behalf of radiation were starting to strain the collective credulity.[201]

One antidote to that was direct engagement with these new energies, and even in its earliest days, American nuclear culture was to some extent participatory. Even setting aside clinical exposures and traveling wonder shows, the new ionizing radiations were no more practically forbidden to the laity than were the transmitters and receivers for the radiations in the radio band of the spectrum. And just as there were at about this time radio hobbyists, electrical tinkerers, and amateurs who strung up local private telephone wires across neighborhood hedgerows, there were also dabblers in x-rays and radioactivity. An x-ray machine salesman recalled a pair of North Dakota teenage boys who had assembled their own x-ray generator from parts in 1910, and for good measure gone on to reduce radium from samples of pitchblende ore that they had acquired via mail order.[202] For that matter, low-concentration radium preparations themselves could be had from chemical supply companies, who advertised in the back pages of books aimed at ambitious amateurs.[203]

Alternatively, the interested amateur could experience the new rays in an old-fashioned way. Much groundwater, particularly in hot springs that arose from deep within the earth's crust, was found to be radioactive shortly after the turn of the century. This reinforced the perception of radium as an inherently vital thing: as the following chapter discusses, radioisotopes dissolved in their waters provided the Western health tourism industry with a compelling new argument in favor of the spa cure. When, in 1904, a prospector hoped to interest an investor in radium ores, but could not immediately send samples, he cited the fact that the waters flowing through the claim had cured several illnesses as proof of their radioactivity.[204] These and many other stories about miners' cures and Native Americans' supposed reverence for certain hot springs seeped into the nascent nuclear culture, and spurred on demand for radium cures in subsequent decades.

But on the whole, American nuclear culture in its earliest years was more a rhetorical matter than an experiential one. Gradually, this began to change. With every passing year, x-ray machines became simpler, cheaper, and easier to operate, and the range of complaints for which they might be used grew. As they became more and more common, it became harder and harder for physicians to do without them: even those unwilling to become "x-ray doctors" themselves had to be prepared to refer patients to roentgenographers, or risk losing them altogether. The domestic radium extraction and refining industry began to come online in the 1910s, establishing the distribution networks through which radium traveled in every form from raw ore to sealed medical ampoule. Even as physicians lamented the scarcity of refined element, radioisotopes in unrefined (or, frequently, unreal) forms found their way into consumer culture. The American public had been transfixed by the rays while they were scarce; their ubiquity in the decades that followed served to focus the chaotic mix of impressions formed in the midst of all the excitement.

Chapter 3

Commodification and Democratization

"RADIUM. No one element has appealed to the scientific or popular mind with so much mystery." So began an advertising pamphlet touting the virtues of the Eastern Luminous Indicator Company's product line, circa 1910. Advertising is always self-serving, but no potential customer would have disputed this particular claim. Radium had come through the frenzy of its debut years with both its appeal and its mysteriousness very much intact, for scientists and laypersons alike. In the two decades that followed, that mystery would give way to something almost like familiarity, thanks in large part to the booming trade in radioactive (or at least allegedly radioactive) products.

The first years of American nuclear culture had been characterized by a sort of echo chamber effect, in which the mythology that quickly accreted around the new energies was only occasionally and glancingly brought into contact with direct experience. Even these encounters were often shaped in one way or another to actively influence the impressions that the laity received: educating the attendees at a public lecture and treating the sick were worthy goals, but popularizers and physicians alike demonstrated a sensitivity to the value of showmanship in their exhibition of the new energies.

The nuclear franchise expanded dramatically in the 1910s and 1920s. The physical experience of radiation became more common, less mediated, and more commercialized. With diagnostic x-rays becoming the standard of care, Americans were irradiated more frequently; they often had occasion for nonmedical exposures to those same rays. A flood of creams, pills, muds, cloths, and jugs all containing radioactive elements—or at least the promise of them on the label—gave form and substance to the promises that had been made for radioactivity.

The rhetoric of radiation was changing too, and with it, the overall tenor of the term's meaning. The discourse at the turn of the century had seen expostulations of terror, enthusiasm, and every emotion in between on the subject of the new energies, and if generally positive and optimistic sentiments prevailed, it was still a crowded connotative space. It could hardly have been otherwise: a layperson might have formed almost any sense of x-rays and radioactivity, because they might have heard scientific and medical authorities promoting almost any theory of their origins and properties. In the relative calm that followed that storm, it became possible, for the first time, to say something absurd about radiation. Likewise, certain tropes gained strength by virtue of repetition: radium's standing as a nature cure was cemented, the process by which the first generation of radiation scientists were mythologized accelerated, and x-rays continued their connotative transformation from an ethereal mystery of nature to a potentially dangerous product of technology.

New kinds of actors became participants in this second phase of American nuclear culture. Healers of various stripes presented prospective patients with a variety of modalities of ray-treatment. Entrepreneurs presented health-seekers with a chance to experience the purported healing powers of rays (especially those of radium) without any mediation whatsoever through the purchase of elixirs, ointments, water treatments, and the like. Other vendors exploited the perceived applications of those energies in everything from cosmetics to fertilizers. Science fiction and popular science writers added a new dimension to the standard newspaper fare about radium and x-rays, while poets and artists codified the emerging consensus on the symbolism of the new energies.

Radium Scarcity and Demand

In the first years after the introduction of x-rays and radioactive substances, the laity's encounters with them were largely beyond their immediate control. In medical contexts, where the most direct and literal contacts with radiation took place, a patient's ability to demand or refuse an x-ray was constrained by their actual medical needs, and whether or not their doctor owned a machine that could generate them. More casual irradiations—x-ray portraits, or public exhibitions like the ones Edison presided over in 1896, were far less common, although much discussed in the newspapers when they were available. The blanket coverage that x-rays and radium received in the print media was also essentially an involuntary proposition for the public:

there was plenty on it for newspaper and magazine readers to read (whether they had an interest in the subject or not), but less in the way of accessible treatments of the new energies in other media.

The relative inaccessibility of x-rays was more a matter of logistics: while the level of technical skill needed to cobble together an x-ray emitter was not beyond the ability of most of the laity to acquire, if it suited them, it was still relatively uncommon for those without a direct financial or professional interest in the rays to bother. The fact that radium was all but impossible for most Americans to come by was ascribed to more sinister factors. In the first years following radium's debut on the public stage, a European cartel was generally held responsible for the refined element's rarity. The highest-grade radium ores were found in Bohemia, and virtually all refining took place in Europe. By the mid-1910s, lodes of somewhat inferior ore had been proven in the Rocky Mountain states. Even with this new source, the value of refined radium was high, and editorial pages in those states began militating for government assistance in breaking the overseas "radium trust." The concern was not a purely local one: for example, in 1914 national digest *Current Opinion* declared the "Increasing Gravity of the World's Radium Crisis," brought on by a 15-gram-per-year demand in the wake of promising cancer results, and noted the potential of federal action to control the nascent US radium market.[1] *Current Literature*, likewise, inveighed against the wasteful use of radium for illumination while the medical supply was still artificially tight.[2]

In 1914, Franklin Lane, the secretary of the interior, proposed nationalizing the mining of radium-bearing ores. This provoked fierce public debate in Colorado, but whether radium would, could, or must be drawn out of the Rockies at all costs was not part of it—only whether government intervention was the best way of avoiding a similar domestic trust from being established. Editorialists carefully took Coloradoans through the finer points of radium mining, the economies of scale and coproduction of other minerals that were a necessary part of it, and the urgency of demand that was beginning to be felt by the rest of the nation for medical-grade radium. Usually unstated, but always palpable in the hundreds of articles and editorials devoted to the subject, was a sense of the heroic rewards that would follow from the proper establishment of a local radium industry, and that was matched by the growing chorus from physicians outside the state.

Howard Kelly, a Baltimore physician, and several other doctors who used radium in their practice testified before Congress in strident and explicit terms about the ravages of radium-remediable diseases like cancer, and the difficulty in obtaining it from overseas sources. But Kelly's support of Lane's plan to withdraw public lands from radium mining—an action that claim-owners said would delay rather than enhance initial production—at a time when he controlled much of the radium already available for medical use was controversial in the extreme, with one mine owner publicly accusing him of conspiring to keep the public ignorant of radium's benefits until it most profited him for them to learn otherwise.[3]

That charge was unfair; Kelly was already independently wealthy and showed no ambition to use his radium affairs to increase his wealth. But the target was well chosen: Kelly was a radium evangelist at a time when the public was eminently willing to listen to the sermon. The intensity of Kelly's campaign was driven by his personal conviction—shared at length with reporters during what amounted to a one-man charm offensive—that doctors required larger quantities of radium for each individual patient in order to treat more refractory cancers. "With more radium we could accomplish more," he told the *New York World*, "as a 12-inch gun would accomplish more than many pistol shots."[4] Switching metaphors to address the Women's Medical Society of Washington, he told attendees that "massive cancer requires massive radium treatment. I have one gram of the element, which is more than any other individual in the world, but for adequate treatment of my patients I need from five to ten grams.... [W]e cannot put out a large conflagration with one bucket of water."[5]

With few enough physicians able to lay hands on any quantity of refined radium, and so many patients in desperate need of it, Kelly painted a wretched picture for congressmen, lecture audiences, and any journalists willing to listen. His colleague Robert Abbe, he testified, had "patients who are crying night and day, 'Give us more radium.' He could not give me any of his any more than I could subtract from the $125,000 worth that I have in the Bremner case." Bremner was the New Jersey congressman whose eventual death from cancer, in spite of his access to radium, had so piqued the *New York Times* editorial staff. His failing health was the subject of daily reports, and formed a grimly pessimistic backdrop for the proceedings. Lest Bremner's Congressional colleagues miss the point, Kelly added that his patient was "hopeful. Sometimes like a child he calls to me: 'Oh, look, doctor, I can move my head better. I think the cancer is getting smaller.'"[6] Bremner died two weeks later. Lane promptly declared that Bremner had insisted on being treated with Kelly's full gram of radium even though his doctors thought that such an exposure would be inadequate. He had done so not in the hope of a cure, Lane eulogized, but in order that the "experiment" would inform future research on high-dose cures.[7]

But Kelly's testimony about his still-living patient's condition was, at least on its face, a violation of his duty of confidentiality to Bremner, which prompted an inquiry from the Medical and Chirurgical Society of Maryland and was seized upon by the coalition of interests opposed to the Lane plan. The response that this provoked is instructive: general outrage from all quarters, not so much on Kelly's behalf, but against the notion that any quibble of medical ethics should inhibit any aspect of the public debate about so important a subject. Invoking the garret inventor, the *New York World* wondered "if a doctor seriously believes that he has made a discovery of great value to humanity, is he to be barred from speech except upon the advice and consent of less progressive scientists?"[8] Striking a more populist tone, the *Press* of the same city held that "Dr. Kelly's best justification for talking about his radium work is that everybody wanted to hear from him about it. The subject is a tremendously big and important one and the public will stand by the men who want to give it the utmost illumination."[9] A Delaware paper went still further, sputtering that it was the "reactionary fossils" of the Society "who are being 'tried' before the bar of public opinion, and the verdict even now is that they have already succeeded in making an exhibition of that part of their anatomy whose public exposure is generally regarded as altogether indecent."[10] Indeed, the fossils largely concurred with the consensus, letting Kelly off with what amounted to a friendly warning because of the weight of the public interest in radium therapy.[11]

Bremner was not the only high-profile radium patient in the momentary excitement occasioned by the hearings: a prominent Methodist bishop's daughter was also under radium treatment for cancer, and was similarly the subject of day-to-day reportage.[12] The social prominence of these and other patients was impossible to miss; a Kelly ally remarked that as things stood, radium was merely "a rich man's cure" for cancer, "the poor man's disease."[13] A physician contemporary of Kelly's lamented that being one of the rare few doctors with medical-grade radium at hand brought physicians the risk of being labeled "extortionists—whether or not they are such."[14] From the perspective of the typical patient, the expense of the stuff was a greater obstacle to a cure than the fact that radium application was an unproven and risky experimental therapy. This mundane economic reality about the scarcity of refined radium helped fuel popular interest in the health applications of low-grade radioactive ore.

Yet as expensive as hospital-grade radium was, it went missing with some regularity. Theft of the portable fortune in even a fraction of a gram seemed likely enough, and when a hospital's supply came up short, doctors frequently assumed that nurses or janitors had given into temptation. This was what drove the plot of the 1915 movie *The Radium Thieves*, in which a half-million dollar supply in transit overseas for a hospital was taken from its physician-courier, only for the thief to be unmasked when he suddenly went blind from exposure. Astonishingly plausible by the standards of radium fiction, in reality medical radium was rarely stolen. It would have been very difficult to resell; the best most thieves could hope for was to ransom it back to the hospital they'd stolen it from.[15] Hospitals burglarproofed their radium vaults anyway.[16]

Much more often, medical radium was simply misplaced during patient care. The tiny sealed capsules were easily missed amid hospital clothing or surgical dressings, or ground into the floorboards. Occasionally, not knowing why they shouldn't, patients simply walked out the door with it still applied to or embedded inside their bodies.[17] When radium was lost, hospitals called on specialists like Frank Hartman, a Philadelphia radium reseller who had made a sideline of recovering it. Newspapers delighted in reporting on the work of "radium hounds" like Hartman: not only was missing radium the financial and dramatic equivalent of a jewel theft, but such stories fit comfortably into established tropes about radium's rarity and importance. The *Philadelphia Record* summarized one of Hartman's exploits: "Credit Hahnemann Hospital with the year's best mystery thriller. . . . A priceless radium needle disappeared from an operating room! A nurse's job hung in the balance!" and from there launched into an account of how Hartman, using a "radium detector, a scientific gadget that might have been born in the brain of H.G. Wells," scoured an entire floor plus an eleven-story incinerator shaft before finding the radium.[18] Robert B. Taft, another professional hunter, compiled 107 distinct accounts of lost radium, which was partially or completely recovered in 70 of them. This included the memorable case of a pig that, having consumed a discarded capsule in its slops, was singled out from its herd by the telltale ionization of its breath, and slaughtered on the spot.[19]

In Hartman and Taft's accounts of remonstrating with careless doctors and nurses, the fear of local contamination by radioactivity, so central to postwar nuclear culture, can be seen taking root. The radium detectives' search was overwhelmingly thorough and occasionally personally invasive, and whether for reasons of finances or safety they tended to approach their jobs with a sense of extreme urgency. Hartman's press clippings, which he archived, suggest that the citizens of Philadelphia might have had the impression that radium went missing every few weeks or so in the late 1930s, but the story was already a well-worn one. *Popular Science* featured Hartman in 1940 under the heading of "Odd Occupations"; it had done as much for a different radium detective, a University of Rochester physicist, in 1920, and in between any number of other stories had appeared to reassure the public that every speck of medical-grade radium was constantly accounted for.[20]

Nonmedical Radioactive Products

That careful attention to the clinical stockpile was necessary in light of the tight supply. In spite of physicians' pleas, not every microgram of refined radium went for clinical use. A great deal was used in the manufacture of self-luminescent paints—as much as 70 grams between 1913 and 1920, according to one estimate.[21] By comparison, the entire United States in 1938 had approximately one hundred grams for medical use.[22] There had been sympathy for appeals like Kelly's to increase the supply of refined radium for medical purposes, but the commercial allure of radium paint was immense. As with other radioactive products, the rhetoric of modernity and novelty suffused ads for radium-painted objects. "*Science* gave us Radiolite," an ad for Ingersoll watches read, adding for emphasis that "radium is a comparatively new *scientific* discovery" before launching into a capsule history of the industrial development that had led to the creation of their line of luminous-dial watches.[23] Even the glowing cross from the "Eradium" line of Pioneer Corporation products was billed as "something brand new in luminous crucifixes."[24] The ads further reiterated their attachment to the modern scientific establishment by explaining the science behind the glow. The Eastern Luminous Indicator Co. provided potential customers with a six-page pamphlet densely packed with explications of radioactivity, the concept of a half-life, how radiant energy caused certain compounds to glow, the comparative merits of those compounds, and the principle behind the curious fact that compounds richer in radium stopped glowing sooner than less potent mixes.[25] This was in sharp contrast to radioactive medicines, nostrums, cosmetics, or other applications in which the benefits of radium had to be inferred, and the principle under which it acted had to be left to the imagination of the consumer.

Glow-in-the-dark articles had existed before radium paint had been invented, and many (though not all) of the ends to which radium paint were applied could be achieved by mundane phosphorescent materials. The novelty of radium, rather than of its effect, accounted for the considerable interest that consumers showed in Undark, Marvelite, and Radium LUMAnous Compound, and other commercially available paints. That novelty was sufficient to sell four million radium watch dials in 1920 alone.[26] (See Figure 3.1.) Advertisements stressed the utility of a permanent light source heavily and imaginatively, and downplayed decorative or frivolous uses (perhaps trusting users to find their own), but did comment on the aesthetic appeal of the dim whitish-green light. For all that radium had become associated with modern convenience, its use as a light source was limited largely to places where electricity was too dear to use excessively, or absent entirely, as many houses and outbuildings still were in the 1920s. To the owner of such a home, the appeal of the Pioneer Luminous Match Box—a useful and "attractive novelty" that ended the tedious process of fumbling for a match for the gaslights—could not have been entirely based on its practicality.[27]

The greenish light of phosphorescent paint, easily and cheaply manifested, was widely employed by commercially oriented concerns to demonstrate the permanence of radioactive emanations. Perhaps more importantly, they served as a guarantee that the bearers of these cards were, in fact, dealers in radioactive materials. Calling cards for such businesses with legends like "This Spot Contains Radium" are ubiquitous in collections dealing with nuclear ephemera, though the paint itself has invariably flaked away. The text accompanying told recipients how to view the light given off by the radium, and then, according to what point the sender wished to make about his product, what that light signified. For the Radium Luminous Material Corporation of New York, it was a product demonstration. For radium-tonic salesman William Bailey, it "clearly illustrates how the constant mild radiation [of his tonic Radithor] acts on the tiny cells of your body, like rays from the sun, to re-energize weak and sickly cells and thus cure many physical ailments."[28] For the American Radium Corporation, a manufacturer of radium emanators, whose calling cards instructed holders to first expose the "radium" spot to bright light (suggesting that the spot was simply phosphorescent paint) it was probably just a promotional gimmick.[29]

Radium's association with luminescence (but not, thankfully, its actual luminescent qualities) was put to good use in selling cosmetics

Figure 3.1 Undark brand radium paint. Phosphorescent paints glow brightly in the presence of infinitesimal amounts of radium or other highly radioactive substances. This was an appealingly modern way to provide bits of nighttime illumination at a time when it was still sometimes inconvenient or impossible to arrange for ample electric light.

and skin care products. The makers of Radior, one of the more prominent brands, devoted several pages in a thick advertising pamphlet ("Radium And Beauty") to quotations of thick, clinical jargon from medical journals on the successful use of the element in treating various diseases of the skin like shingles, rosacea, and eczema. The connection to physical appearance made the elision to its cosmetic use an easy one, since the care of one's skin was a matter of hygiene as well as aesthetics, and both thus fell within radium's "marvelous *powers for betterment* of the skin."[30] This was especially appropriate considering that, regardless of their actual radium content, radioactive cosmetics were physically interchangeable with the innumerable radioactive ointments represented explicitly as medicinal that appeared on the marketplace at the same time. The belief that radium performed some sort of bodily revivification was sufficient reason for manufacturers to include a trace of radium, or at least to claim that they had done so. The expectation that bringing radium near to one's body would effect *some* sort of change was strong enough that, for all its patient and surprisingly detailed accounting of the physics of radioactivity, Radior's advertising materials never addressed the mechanism by which their products worked.

Rather, they focused on how well they would work, and to what extent. Radior was not merely "delightful to use" but also "delightfully safe . . . the effect of the 'Radior' preparations is *entirely a natural effect*." Obscurely, that passage added, "they do not, for instance, promote the growth of hair on the face where Nature intended no hair should grow."[31] Unwanted hair growth was not often bruited about as a potential side effect of exposure to radioactivity, but the invocation of nature—or, more generally, the deliberate and pointed reminder that radium was a naturally occurring substance, was frequently used to allay concerns about its safety. Another brand, Narada Radium Preparations, simply declared that its products contained "radium element in sufficient quantities to produce amazing results."[32]

Given how famously scarce radium was, that sort of reassurance was commercially necessary.[33] Radior, in particular, went to considerable lengths to convince its customers that it contained the genuine article. It peppered its advertisements with radiographs, and an explanation of how only a radioactive substance could produce such images on unexposed film. It offered a $5,000 guarantee that its preparations would "contain a definite quantity of Actual Natural Radium, and retain their Radio-Activity for at least 20 years."[34] Attentive readers of the considerable volume of accurate, digestible scientific information about half-lives contained within the same pamphlet might have sensed something amiss with such a guarantee—radium cosmetics should retain their radioactivity far longer than that—but the makers of Radior clearly felt obliged to strenuously assert the product's legitimacy as a condition of market viability. They were not alone among consumer radium firms in that regard, and the concern was a reasonable one. No government agency had the authority to ban radium products on the basis of radioactivity until the late 1930s, but the Federal Trade Commission frequently took legal action against vendors for false advertising when their products were shown to have *insufficient* radioactive properties to justify their claims.[35]

Collectively, these products were conduits for the dissemination of information about the physical nature and potential medical applications of radioactivity. They were affordable, alluring, and sold by mail-order or commissioned agents, which meant that they were within the grasp of most Americans. They were, if nothing else, generally at least as useful and effective as their nonradioactive counterparts: the soap lathered, the rouge reddened, and so forth, incurring no particular resentment even if buyers perceived no extra benefit from the added radium. Manufacturers did *not*, however, either assume any particular knowledge on behalf of their audience with respect to radiant energy or how it might operate in the context of their particular product. Instead, they meticulously (and occasionally rather defensively) provided, in thousands of different pamphlets and circulars, a primer on the nature, theory, and application of nuclear emanations. Nor did they gratuitously leave themselves open to accusations that they were making claims beyond their areas of expertise as, say, makers of cold cream. Invariably, physicists and doctors were invoked as the guarantors of whatever extraordinary capacity was being attributed to radium.

Just from the labels of these products, consumers could get a rough and ready education on the novel energies. This form of popularization was generally accessible by design and usually quite accurate, the better to flatter consumers' interest in the workings of radioactivity or radiant energy while simultaneously instructing them in the benefits of the product. The hierarchy implicit in having regular and "radium" versions of the same product, too, reinforced the folk ontology that had grown up around the element: radium was a physical embodiment of the superlative that could literally be ground up and mixed in with fertilizer or toothpaste.

When the Worthington Golf Ball Company produced a model in 1910 with an allegedly radium-laced core—the "Radio"—it was playing to the expectations that the word signified a special kind of power.[36] (Another golf ball manufacturer marketed the X-Ray ball at roughly the same time, although apparently the term was meant only to evoke its piercing, powerful flight, not to describe any secret of its manufacture.[37]) To bend radium, which threw off its power carelessly and ceaselessly, ingenuity and effort were required, and so most commercial explications of radiant energy also dwelled on the scientists who directed their own energy back at it. The story of radium's discovery by the Curies (or just Marie Curie) was a favorite touchstone in commercial literature, as were capsule summaries of Becquerel and Roentgen's discoveries, the better to establish an intellectual pedigree. Many wholly commercial enterprises even adopted the terms of the scientific establishment into their names: Bailey Radium Laboratories, Denver Radium Laboratories, Paradox Radium Laboratories, Spectro-Chrome Institute, and so forth.

The vitalism of consumer "radium" was extended to more than just human life. The perception of the element's biological effect was reflected in (and burnished by) the presence in the marketplace of products that would revive or invigorate dogs and houseplants in the home, or pigs and crops on the farm. The Radium Mines Company was probably overstating its case when its ecumenical advertisement in *Field And Fancy* for "Kennel Supplies—Real Radium Remedies—For Dogs And Men" claimed that its product contained 7 percent radium per two-pound sack. That would have been difficult for even mildly attentive consumers in 1922 to believe, rather like a pharmaceutical company today claiming its cold remedy contained 7 percent human stem cells.[38] But the American Roost Manufacturing Company's plan to advertise radium-based cures for pigs (necrotic enteritis) and humans (trench mouth) alike in farm publications—scotched when the Better Business Bureau intervened on the advice of the AMA—would have seemed perfectly plausible to consumers whose understanding of radium's effect may have been derived in large part from what advertisers taught them. Radium was not subject to drug laws, and, except for certain limitations on how its preparations could be marketed, the innumerable and ephemeral business concerns that produced radium tonics for medicinal purposes often had nonmedical lines as well. The Radio-Active Chemical Company of Denver sold radium products that ranged from the explicitly medicinal ("Sanable Healing Balm") to the quasi-medical ("Sanable Radio-Active Foot Powder") to the miscellaneous ("Sanable Radio-Active Soil Stimulant") in the same pamphlet, with the pictures of overgrown lettuce heads appearing over testimonials for the soothing effect of Sanable Radio-Active Bath Powder.[39]

Other radioactive fertilizers were on the market, too, including that of the Radium Fertilizer Company of Pittsburgh, whose 1915 advertisements in the *Washington Post* are a case study in the way that advertisers leveraged the scientific and "natural" status of radium to commercial advantage in the form of compact primers on the underlying physical phenomenon. The thesis of the Radium Fertilizer Company ads—spelled out in small type supplemented by photographs of luxuriant plants—was that plants, like all growing things, required food, "and the food element in your soil has become partially exhausted by years of use without replenishment." Accordingly, in addition to phosphates and potash, their product contained "the wonderful NEW ELEMENT which gives strength, health and quality to growing things." Lengthy testimonials from professors and pharmacists follow, after which it is carefully explained how so reasonably priced a product can contain so valuable an element. (The answer given is that radium is so powerful that only a tiny amount is necessary.) Radium's energies are described by reference to how deeply its rays penetrate (through four inches of lead), how coal would equal the energy in a gram of it (half a ton), and how similar its radiance is to the healthful ultraviolet light of the sun. A table listed the increase in yield from radium fertilizer for 30 crops, from black beans to turnips, in an experiment performed by the Dean of the College of Pharmacy at Columbia, who concluded that "plants are living things and require food while they are growing. Radium Fertilizer, or plant food, supplies this nourishment *in a scientific way*."[40]

Radioactivity, in short, bestowed an aura of benevolent scientific correctness on everything it touched—or was alleged to have touched—in an era when the cultural potency of science was keenly felt. The advertising campaigns it was enlisted for reinforced that association. But radium, the element itself, did not exclusively connote the laboratory. Its earthy origins meant that it could also be pressed into service by different kinds of commercial actors.

Radium Becomes Natural

The belief that radium could be consumed as a health tonic originated in the first decade of the twentieth century, but remained functionally absent from the experience of most Americans. Only a very small number of the wealthiest patients could be treated by exposure to refined radium at any given time: there were only a few grams split between a handful of clinics. Nor could radium be created by entrepreneurial sleight of hand: the perception of its rarity was so strong that in the first decade or so after its discovery that even fraudulent radium tonics had not yet appeared in force on the market.

There was one exception to this rule. In 1903, J. J. Thomson reported that water from very deep wells contained a radioactive gas.[41] The subsequent discovery of natural radioactivity in spring waters immediately suggested that the cause of the long-suspected benefits of "taking the waters" had been found. The federal government, which administered the waters at Hot Springs, Arkansas, had them tested in 1904, and other spas and resorts followed suit. They did so in part because the question of *why* bathing in mountain springs or drinking hot sulfur water in Arkansas seemed to have a salutary effect was an open one among the doctors who referred their wealthier patients to those baths. The discovery of natural radioactivity did not so much enable spa owners to *start* making claims about health benefits, but to lend credence to the claims that they were already making, putting the cause and effect relationship on a surer and more ostentatiously scientific basis. By the middle of the 1910s, thermal springs were undergoing a renaissance as places not merely to take the waters, but to take the radioactivity.[42]

The language of radioactivity found its way quickly and prominently into the advertisements for the spas. Those for Hot Springs, Arkansas, were probably the most widely distributed: the Hot Springs Chamber of Commerce diligently ran a series of ads in Eastern and Midwestern newspapers that trumpeted both the springs' radioactivity and the involvement of the federal government. In the Chamber of Commerce notices, a cartoon Uncle Sam spoke of the region's "46 fountains of youth," and proclaimed that "the medical properties of these steaming hot Radio Active waters have a way of ridding your system of rheumatic, high blood pressure, etc., and making you feel ten years younger."[43]

This was not the jargon-heavy hard sell of the cosmetic industry, however. Though dozens of different ads were published in nationwide campaigns for the Arkansas springs in the 1920s and 1930s, and most of them mentioned radioactivity, they did not discuss or even refer to the physical properties of radioactivity. The same is true of the various local guidebooks or other sorts of promotional materials created by the resort businesses themselves. Instead, the radioactivity in the water—though prominently (and by the mid-1910s, infallibly) mentioned, is represented exclusively in terms of its vital or healing potential.

That kind of language is significant because it underscores both the hope that people were investing in these radioactive waters, and the way in which it was becoming pinned down geographically. In the first blush of its appearance in the public sphere, radium and other radioactive materials were not closely associated with any particular place on the US map.[44] Until Western spa owners or bathhouse owners started having their waters tested, there was no good reason for Americans (except a few geologists and physicists) to have any sense that Colorado, Utah, New Mexico, or Arkansas had any kind of special connection to radioactive substances. The notion of the "radioactive West" that would so clearly characterize the postwar concern with fallout from nuclear testing, the Navajo Uranium miners, the Yucca Mountain controversy, and Los Alamos, has its real origins in the public relations campaigns of bathhouse owners.

Notwithstanding the best efforts of resort owners to encourage health tourism, most Americans could not make a trip to the spas. It was difficult to travel in the mountains, it was time-consuming, and like so many things having to do with radioactivity, it was something really accessible only to those with money. The solution that many spring owners hit upon was to bottle their water on site and ship it—not an entirely new idea, in a country that still suffered from fits of suspicion with respect to its municipal water systems, but one that the measurable radioactivity of the spring waters could make especially attractive to middle-class households in Chicago or New York. But there was an unforeseen problem with these bottled waters: by the time they reached their destinations, they were no longer radioactive. In transit, within a few days, the dissolved radon gas that was responsible for most of the measurable radioactivity would escape. Nor was this fact easily glossed over by the bottlers—there were enough people looking into these claims (including the Federal Trade Commission, by the mid-1910s) that the appeal of these waters was greatly reduced and their ability to make plausible claims about radioactive health benefits greatly curtailed. In fact, the idea that spring waters lost their virtue when bottled and shipped predated radioactivity by centuries: similar imprecations had been leveled against water taken from European spas, for instance. Therefore, the recognition that something radioactive was also being lost when water was taken from its source powerfully reinforced the idea that radioactivity was that healthful virtue that had been at work in spring water and natural baths all along.

The nature of that radioactive substance that was being lost, the radium decay product radon, was first identified in 1900. In 1908 it was recognized as a separate element rather than a vaporized or gaseous form of radium, although it was generally referred to as "radium emanation." Potential spa-goers were duly warned by the spas' promotional literature that there was a radioactive healing virtue to the hot springs that would not—could not—be transported away. On one level, this was something that Americans had always understood, at least since the mid-nineteenth century when the mountains had become places of refuge, of sanctuary—first from malaria, and then from tuberculosis. In fact, the healthfulness of the Western mountains had already been given a radiant-energy gloss via its association with heliotherapy, and the penetrating (highly ultraviolet) rays that shone there.[45] With geologists' reports confirming the radioactivity of the waters at bathhouses up and down the Rockies, the stony ground itself could be enlisted in the rhetoric of health that resort owners and interested physicians promulgated for the Western states.

Therefore, the West could not be brought to the people in bottles, and the people could not, for the most part, be brought to the West. A technological solution arose in the form of a device known as the radium emanator. There were hundreds of variants on the same operating principle: a bit of low-grade radium ore was introduced into a container of water, and the decay of the radium released a small but detectable amount of radon into the water. In many models this was accomplished simply by grinding the ore directly into the ceramic slurry that would form a standard water jug. Unless an electroscope was brought very close to one, these emanators would have looked exactly like any other household water pitcher.

Contrary to the example set by radium tonics and nostrums, most emanators apparently did contain some quantity of radioactive element, though the Federal Trade Commission (FTC) and other investigators occasionally asserted that they contained less than advertised.[46] The first emanator sold in the United States was patented in 1912 under the name Radium Ore Revigator. (See Figure 3.2.) Emanators remained a fairly common accoutrement of middle-class life until about the mid-1930s, when the abrupt change in the prevailing mood toward radioactivity more or less ended their commercial viability and—presumably—their widespread use in the homes that already possessed them.

The emanators were an emblem of the trip out to the sacred places in the West to take the waters. They were designed specifically to manufacture precisely those waters anew in places whose water supply lacked the relevant virtues. But the marketing for these devices did not simply rely on people to know that those healing waters were out there; they actively made the connection and, in fact, educated the public about them—simultaneously creating a demand for their product and acculturating the public to the new notion of the radioactive West.

For instance, a 1927 advertisement for the Revigator asked the question, "Why take an expensive trip to one of those famous health

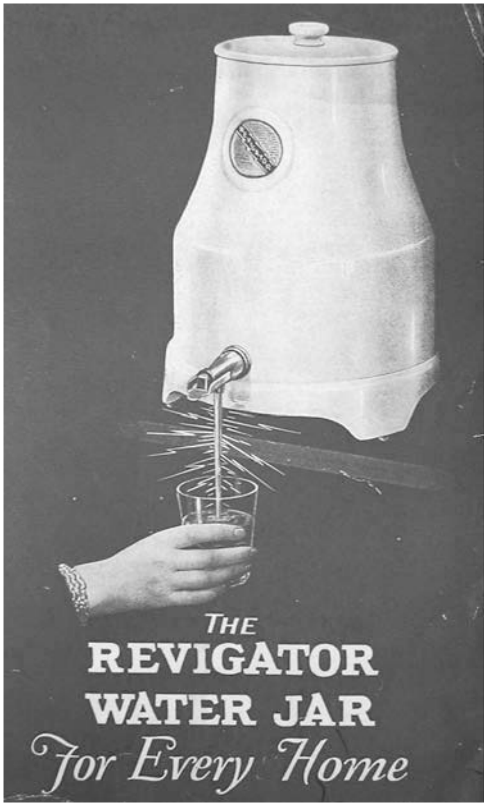

Figure 3.2 The Radium Ore Revigator, the most popular brand of radium emanator.

springs?" when one could have the same benefits in the home for a fraction of the cost, before segueing on into a litany of the benefits of radioactive waters.[47] Indeed, Revigator advertisements in the 1920s usually touted them as "a perpetual health spring in your home." The pamphlets for the Revigator and its many imitators are in and of themselves a capsule history of the hot springs of the American West, or at least a history of the springs as represented by the medical tourism industry, with references to the European springs once again cropping up as a point of comparison. "Don't drink [Revigator water] with the attitude that you are trying something new," the Revigator manual cautioned, but "accept it as the blessing it is, for the famous springs of the world such as Gastein, Hot Springs Ark., Vichy, France, have performed health miracles for centuries. And it is now agreed that this is due to the high radio-activity of the water. *The Revigator* *truly duplicates the radio-activity of these springs.*"[48] Another Revigator ad spoke of "A lucky town in France: . . . Glad news from the little town of Estreyes in France. No one in the town ever has cancer or dies of that fearful disease. There is a highly radioactive spring in the town and everyone drinks the water from it—apparently the water PREVENTS the cancers."[49] One manufacturer simply called their product the "Radium Spä," noting that the ore lining their water jug "imparts to the water placed therein millions of tiny gaseous particles known as Radio-activity, in exactly the same manner as Nature does herself." The benefits of the world's famous radioactive spring waters were thus "sold at a price you can afford to pay," it concluded.[50]

The emanators helped to democratize radium. Before the Revigator and its many imitators came onto the market, radium had been portrayed as the province of one sort of elite or another. It was widely known that even wealthy patients and influential scientists went begging for the stuff, and if it could be had in some diluted form from a spa trip, that was nevertheless too high a price for most. The rumblings about radium cartels and the inevitable mention of an arbitrarily high per-gram cost in any public discussion of the substance meant that none of its characteristics were so well-known as its hyperbolic difficulty to acquire. Yet radium emanators were ubiquitous—discounting patent medicines, the only way that ordinary Americans could have access for themselves to this otherwise almost preposterously rare substance. Buying a radium emanator for your home did not merely get a consumer a "perpetual health spring in your home," but a piece of something fantastically rare at reasonable prices. It became, in other words, a prestige purchase much as a diamond ring or a new automobile might be—not necessarily an extravagance, but something that marked the owner as having entered in some small way into a better lifestyle. Depending on the model and the year, an emanator might cost anywhere from $20 to $500: not nothing, but, as the manufacturers were quick to point out, it would never need to be replaced.

Radium emanators raised the status of those who owned or used them: many manufacturers targeted their sales at hotels and business clients. By 1925, the makers of the Revigator felt confident enough to make this claim to the Statler Hotel in Chicago: "It is only a question of time until all hotels and restaurants will serve radio-active water not only as a matter of service and convenience, but as a health measure the same as filtering water, cooling water, or other improvements."[51] Perhaps this was optimistic and self-serving, but not completely implausible, given the number of agents selling the devices. The Radium Ore Revigator Company claimed at one point that they had sold 500,000 emanators, which is entirely plausible given that the company was in business nearly 25 years and had a nationwide network of resellers.[52] The figure might at least be taken as a safe estimate for the total number of such devices, regardless of manufacturer. Physicians were among those who acted as resellers or sales agents: they were often as susceptible as the layperson to the health claims that were made on behalf of radioactivity, and were certainly, as a class, interested in the financial benefits that came with referring or reselling the devices.[53] Doctors had been recommending spa cures for years, and so many people were introduced to the Revigator or similar products at the clinic. This is evident from the bulk of correspondence that the AMA received on the subject, and (perhaps less reliably) from the enthusiastic endorsements from MDs that characterized the typical sales pamphlet for the devices.

Yet even though medical doctors sold or recommended these products during the 1910s and 1920s, the overall language of the brochures, the advertisements, and their appearances in the media seems to have been carefully designed to rhetorically separate the healthful, the sanative aspect of the emanators and of radium water, this artificial spa water, from the medical establishment. "IMPORTANT," a typical disclaimer went: "RADIOAK is not a medicine in the general acceptance of that word. It is absolutely not a drug. It is based upon scientific, measurable facts and is not an experiment or a theory."[54] This is partly due to the influence of the drugless healing movement, an influential school of thought that could accommodate rhetoric that focused on the healing virtue of natural waters, but could not accommodate the notion of a drug (that is to say, a foreign chemical substance, a poison by another name) being introduced into the body to do mischief. The much-heralded efforts of orthodox physicians like Howard Kelly to claim radium for medical science might ordinarily have made it a bitter pill for drugless healers to swallow, but the (purported) presence of radium in so many consumer products made it far more palatable: it was, by the 1910s, sufficiently ubiquitous in so many non-allopathic contexts, that it could easily be recharacterized as a mineral supplement.

Tonics and Nostrums

Given the profusion of emanators on the market, consumers were evidently willing to believe that water could be "recharged" by proximity to unrefined radium ore until its health-giving virtues were on par with (or perhaps even slightly superior to) those of natural mineral waters. Spring water was widely regarded as salubrious, and especially useful in the management of chronic illnesses like gout and Bright's disease, but drinking it was reckoned more as a preventative therapy than as a medical intervention for a specific complaint. Patients who wanted stronger medicine—and hence radioactivity in greater than truly homeopathic quantities—had to look to other products. A few patent medicine bottlers were bold enough to put words connoting radioactivity in their product names, as with the makers of "Radium Radia" and "Radium Rings," circa 1904, but their manufacturers freely admitted that they contained no such ingredients, and even printed chemical analyses confirming that absence on the packages. By the prevailing ethical standards of the day, this was not even particularly dishonest. Most consumers, who would have heard about radium's impossibly high price if they had heard anything at all about it, would have put "Radium Radia tonic" in the same category as "X Ray stove polish" and inferred no claims about its content.[55] Here an interesting problem arose for the patent medicine vendors who would otherwise have been happy to oblige the demand for genuine radium tonics. It was not difficult to find Americans who were anxious to consume, inhale, imbibe, or otherwise come into contact with radioactivity; it *was* a challenge to convince anyone that your bottle of medicine contained anything radioactive, and given the relentlessness with which the rarity of radium had been reiterated, offering to sell bottles full of it would have been implausible on its face, at least in the wake of the radium mania.

Dennis Dupuis, better known to scandalized anti-quackery campaigners as Dr. Rupert Wells, came somewhat closer to marketing a (purportedly) genuine radium tonic with his cancer cure "Radol," which he began selling in 1905. Radol, he claimed, was a "radium impregnated fluid" that would retain its radioactive healing properties for 40 days after bottling. This left a little leeway for Wells to claim that he was merely treating ordinary water with radioactivity rather than selling radioactive substances outright. Wells had good reason to worry about these kinds of niceties: successful patent medicine salesmen attracted the vigorous attention of prosecutors and postal authorities, and they eventually caught up with Wells, too, although not before he'd netted something on the order of $100,000 in Radol sales. To prove their case, Radol was tested by the Department of Agriculture and found to contain no more radioactivity than "ordinary hydrant water," but ordinary patients could not have tested the water for themselves. Some other form of persuasion was in order, so to assure his customers of the authentic radioactive nature of his product, Wells cannily added a mild solution of quinine sulphate, an ingredient that caused a faint bluish fluorescence when exposed to light. The Radol promotional literature presented this soft aura as proof that radioactive rays had acted upon the product. It is a good marker of the rapid maturation of early American nuclear culture that just a few years after radium had made its public debut, Wells had to flatter several different popular notions about the nature of the substance—its cost, its vitality, and its ability to make things glow—merely to seem plausible. It is likewise a good marker of that culture's intensity that he became very wealthy very quickly once he achieved that plausibility.[56]

A prominent homeopathic physician, Dr. E. Stillman Bailey, was even cleverer in his reading of the radioactive zeitgeist. His announcement in 1909 of a substance known as "tho-rad-x," composed not of radium but of a mixture of thorium and treated pitchblende (one of the ores from which radium was extracted) garnered considerable attention because he claimed for it a radium-like, radioactive effect—which is to say, he claimed it would do almost anything.[57] It was far easier for consumers to believe that a radioactive mineral might cure "supposedly incurable cases of X-ray burns, cancers, and other serious diseases" than it was for them to believe they might actually possess radium, even in tiny quantities.[58]

The reference to incurable x-ray burns reflects alternative healers' growing distrust of medical irradiation that eventually encompassed radioactive tonics but which started with the radiations that had more effectively been monopolized by allopathic medicine. Indeed, when speaking with a reporter, one of his homeopathic colleagues pointedly referred to tho-rad-x's "moderate action" that "keeps it from being harmfully caustic, as radium is likely to be in the hands of unskilled persons."[59] Nevertheless, radium fears were generally muted in the discourse at this time—Pierre Curie's hypothetical deadly pound of the stuff was nowhere in evidence—and the reception of this "radium substitute" demonstrated that there was a larger marketplace for radioactive nostrums than had previously been exploited. E. Stillman Bailey followed the ersatz radium of tho-rad-x with several further products that were carefully packaged and presented in such a way as to convey that they were similar to radium element, yet somehow not the same thing. He promoted a machine called a "Radia-tór," which collected and concentrated gaseous radium emanation for direct inhalation.[60] He sold tablets of unspecified ingredients for the restoration of "potency" under the name "Nuradium" and later "Becquerelle."[61]

E. Stillman Bailey succeeded in making an impression on the public mind all by himself, if measured only by the thickness of the file kept on him by the AMA's wrathful anti-quackery division. The obvious sexual overtones of "potency" in the ads for Nuradium were surely no obstacle to the product's success: radium's "potency" found a direct application in nostrums that promised to use its energy to cure impotency in men, and indeed the whole spectrum of sexual dysfunction in both sexes. While there were many patent medicines aimed at sexual complaints, ostensibly radium-powered ones were notable for their explicitness and the way in which they leveraged expectations about radioactivity. To take one of many examples, the Home Products Company of Denver offered a separate line of ostensibly radium-bearing products aimed specifically at sexual stimulation (with the exception of the Soothol Radium Bougies, which were intended to have the opposite effect). "Weak, discouraged men" might find comfort in the Testone Radium Energizer and Suspensory (an athletic supporter purportedly containing 20 grams of refined radium), while both men and women were encouraged to try Magik Radium Ointment, a balm that would stimulate genitalia that were "cold, clammy, and lifeless." The Home Products line of radioactive sexual aids, in particular, took on the characteristics of a concurrent fad: products that ostensibly used "glands" and "glandular extracts" were marketed in the same brochure, and while the advertisement as a whole followed the typical pattern of eschewing any technical or jargon-laden talk about the action of radium on the body, it took great care to explain the means by which "glands and radium work together."[62] As with suggestions that radium was bactericidal, or somehow infectious itself, a central part of its appeal as a medicine (or, latterly, the fear it portended as a poison) came from the fact that it was so often parsed as an intensifying adjective for a known effect, rather than a cause of it. If a consumer of that era had already come to the belief that the extract of animal endocrine systems would restore his sexual potency, then the eagerness of radium vendors to conflate the two suggested that they believed that a general sense of radium's inherent power could be commercially plugged into the public's understanding of other modes of treatment.

But the emphasis on vitality and vigor in the marketing of most radium patent medicines was not limited to its implied sexual enhancement. The element had become more closely associated with biological energy with each successive appearance on the public stage: it was underwhelming and impractical as a light source, and no progress had been made toward controlled nuclear fission, but its physiological effect was real and visible, and therefore ripe for exploitation by tonic bottlers. Precisely because the mechanism by which it acted on the body was so poorly understood, and the reactions observed so idiosyncratic, patent medicine vendors were at liberty to treat it as an all-purpose enhancer of "vital forces." As with the emanators, radioactive medicines and tonics frequently eschewed the jargon of the laboratory in favor of the imagery of the nature cure.

Tonics and emanator waters were the most widely available forms of radium therapy (ersatz or legitimate), if only because they were taken internally and thus, plausibly, able to effect cures for a wider and more diffuse range of ailments. Nevertheless, as consumer products purporting to contain the element began to appear—which is to say, as the perception of its scarcity went from absolute to merely extraordinary—some entrepreneurs began producing items that were intended to be used in a topical fashion for the relief of localized complaints. For example, Degnen's Radio-Active Lenses, which were wire-rimmed glass spectacles coated with an opaque greenish film (save for a small clear dot at the center of each lens), capitalized on the perception that mere proximity to radium would have a potent (and holistic) revivifying effect on the flesh to which it was exposed. A similar logic applied to the pads and compresses that allegedly contained radium ore. The Degnen line also included radioactive appliances specifically designed to be applied to the nose, ears, prostate, uterus, and throat; other manufacturers made appliances worn on the gums, insoles, or in trusses.[63] The promotional materials did not dwell on causality, but took for granted that their audiences would assume that radium would have an effect on the tissues brought within the reach of the aura that the substance was depicted with. One advertiser went so far as to essay this much of an explanation for how radium acted on the body:

> If your blood could be frequently taken from your body, exposed to the sunlight and then put back, your physical troubles would disappear and you would remain strong and healthy to a very old age.
>
> Radium emanation has the same effect upon the blood as exposing it to sunlight.
>
> But, while sunlight is unable to penetrate beyond the skin, radium emanation penetrates entirely through the body, reaches the farthest blood cells and tissues and restores them to life.[64]

The copy then went on to claim that the metallic element radium was neither a metal nor elemental but rather "life itself," and conflated "radium emanation" (radon) with the energy of decay. The audience for this class of product was not the casual pop science aficionado, or the careful reader of the newspapers, but rather the class of patients for whom the word itself had ceased to have any particular meaning beyond "energetic."

The most successful (and, eventually, the most notorious) of the tonic vendors was William Bailey, whose claim to infamy was having sold a radium tonic that actually contained radium. Bailey, no relation to E. Stillman, was unusual in several respects among the throng of radium-tonic peddlers. For one thing, his products usually contained actual radioisotopes, although not necessarily at the concentration or purity that he claimed. His most celebrated product, the "triple distilled" tincture of radium called Radithor, was potent enough to cause the deaths of its heaviest users. As the following chapter describes in greater detail, the scandalous decline in 1932 of millionaire and habitual Radithor consumer Eben Byers helped nudge public sentiment regarding radium toward a tipping point. Before then, however, Radithor and the other products of the Bailey Radium Laboratories benefited from Bailey's ecumenical approach to the various connotations and understandings that had accreted around the substance.

For those customers who favored a nature cure, Radithor was "internal sunshine." Just as the emanator manufacturers had done, Bailey presented his sunlight-in-a-bottle as the means by which the sun-deficient enervating modern lifestyle might be conveniently set right. Pacific islanders, the Radithor literature claimed, once had "splendid physical condition and virility" because they were habitually nude beneath the sun, until they adopted Western dress and fell into disease and degeneracy.[65] Even spaghetti, which used to be dried in the nourishing sunlight, had lost its savor and its healthfulness in the modern indoors world. Thus, one needed Radithor to "put the sunbeams in your bloodstreams."[66]

But Bailey, who presented himself and his products as medically and scientifically orthodox, also reached out to consumers who were attracted to things modern, scientific, and industrial. The advertisements for his "Adrenoray," a device that held over the adrenal glands several "gamma ray generators" consisting of chromium-plated radium pellets, were ostentatiously laden with jargon, and linked Bailey's own researches with those of "leading scientists" including "Steinach, Catani, Thaler, Benjamin, Borak, Werner, Fraenkel, and other famous clinicians and röentgenologists." These names would have been no more familiar to contemporary Americans than they are today, but their solemn invocation at the start of a ten-page pamphlet touting the virtues of "biopositive radiation" and the use of "radium as a physiotherapeutic modality in the treatment of the endocrines" established the tone of scientific authority clearly enough.[67] (In ads for a similar product, the Radiendocrinator, which Bailey sold through a different front company—the American Endocrine Laboratories—he was content to list himself as a "Leading Scientist and Authority on Radioactivity" and to give his own testimonial alongside those of scientists of more orthodox legitimacy).[68] Like Rupert Wells' Radol, the Adrenoray could signal its radioactivity by virtue of a strange luminescence. Bailey suggested that his customers bring the device near a quantity of a radio-luminescent chemical like zinc sulphide, subtly flattering their scientific sophistication with the implication that they would have such a material at hand. Wells had merely gestured at the connection between Radol's fluorescence and its radioactive legitimacy, but Bailey's Adrenoray pamphlet elaborated on the mechanism by which the light would be produced, and provided a capsule summary of the latest scientific understanding of how its seemingly perpetual energies would, in fact, imperceptibly diminish over the centuries.[69]

Bailey, a shrewd and successful entrepreneur, marketed virtually identical radioactive products under radically different rubrics because he intuitively and correctly understood the nuclear zeitgeist. Radium was no longer all things to all people, in the way that it might have been in the excitement following its debut on the public stage, but as a medicine it could appeal to patients on either side of the line separating orthodoxy from heterodoxy. Moreover, as a medicine, its virtues were attested to at every turn by voices of unimpeachable authority: Howard Kelly endorsed powerful doses of refined radium for the gravest illnesses, and Uncle Sam himself praised the virtues of the Arkansas hot springs in newspaper ads. Whether a given formulation of a radioactive substance connoted the laboratory or the mountain vale was of less concern to the consuming public, by the 1920s, than its availability in the first place.

Nonfictional Representations of the New Energies

The rush to make radium and x-rays available in some form on store shelves was in part a function of the genuine availability of radium-impregnated dust and mill tailings, part a result of the perception that such stuff was available, but above all a creation of the ray-entrepreneurs themselves. It was not by any means inevitable that the palpable fascination that Americans had with the new energies would find commercial expression; rather, this was the result of the concerted efforts of thousands of financially motivated actors.

There was profit to be had from the idea of radiation, too, and a comparably diverse set of entrepreneurs set up shop in the 1920s and 1930s in order to capitalize on it. In the initial furor over the debuts of x-rays and radioactivity, the periodical press had had the initiative. Influential and widely read treatments of the new energies did occasionally appear in other media, like Soddy's *Interpretation of Radium*, but the very chaos that so attracted the public attention tended to discourage book-length disquisitions. Another shoe seemed too likely to drop while a book was going to print.

Moreover, these intermediate decades in early American nuclear culture coincided with substantial changes to print culture. Science fiction exploded into commercial relevance via dime novels and pulp magazines during the 1920s. School science textbooks underwent a series of paroxysmal changes in response to educational reforms, with the textbook of the 1920s being much more accessible, considerably more reflective of contemporary scientific consensus, and far more widely read than had been the case in 1896. Science popularizations, particularly those written by as well as for nonscientists, increased notably in popularity. All of these changes figure into the evolving set of ideas and images about science, modernity, and fantastic energies that Americans conjured with, not least because all deliberately invoked those new energies as a means of baiting the hook to attract readers.

* * *

Nuclear culture had been slow to permeate the classroom. X-rays and radium did not rate highly in teachers' opinions as subjects of inherent importance.[70] In a 1942 survey of textbook authors and college physics professors, "radioactivity" and "X ray" were among 250 terms regarded to be of "secondary importance" for students to learn during their high school years, behind another 250 terms of primary importance.[71] That was something of a high water mark; a 1931 survey of parents had the topic of radium as the fifth least interesting and the fifth least useful out of 30 topics in the natural sciences (comparable to fossils and volcanoes).[72] A contemporary survey of junior high school students indicated intense interest in chemistry and applied physics, relative to other topics such as biology, earth sciences, and agriculture, but radiation and radioactivity were not among the subtopics surveyed.[73] Very occasionally, teacher-authored articles appeared in the journals that conjured with radioactivity or x-rays in some fashion, but such treatments were negligible compared to the active discussions about methods and principles relating to classical physics or more tractable chemical elements.

Science teachers, however, saw the same potential in x-rays and radium that advertisers had: as a means to glorify their product. A poll of teachers in the same period found great enthusiasm for the idea of revising the physics curriculum to include "the electrical structure of matter and the transmutation of the elements" and "the significance and unity of the entire radiation spectrum." 96 percent of 1,043 respondents agreed that "the 'new physics' has a decided educational and cultural value. The prominence given it in current magazine and newspaper articles is evidence of this."[74]

The journal *School Science and Mathematics* ran an article in 1915 on "recent discoveries concerning x-rays." Ostensibly a refresher, it was in fact a prosecutor's case for recognizing the hold that the new energies had on students' imaginations. Earl Glenn, a private school teacher from Indiana, held forth against the false idol of practicality in science education. X-rays were not mundane enough to meet the threshold of "utility" set by household chemistry or mechanical physics, he argued, but neither would those subjects inspire students to careers in science.

> Shall we emphasize "practical application" to the almost complete exclusion of descriptions of the momentous struggles now in progress in the field of science? The chapter of scientific history that is now being written concerns the ultimate structure of the atom—it may be comparable in interest and possibly superior in significance to any that man has yet written. What order of civilization would follow the discovery of a method for liberating the enormous stores of energy within the atom? And what shall civilization do if such a discovery is *not* made?

The urgency Glenn felt about bringing x-rays and radioactivity into the curriculum was not driven by the thought that one of his students might split the atom, but by fear of missing a chance to evangelize to his students. "Practical we shall be in order to live," he concluded, "but we must not be so *impractical* as to fail to appreciate, and to teach appreciation of present day science and scientists."[75]

Radiation and radioactivity had been treated gingerly by most high school texts before 1920, typically dispensed with in two or three pages of hesitant prose and diagrams tacked on in a new final chapter. A 1902 chemistry text, in its sixth edition, found room in its last paragraph to note that "certain products obtained from pitchblende emit rays that in some respects resemble the Roentgen rays, but in other respects differ from them." It named them there, but not on its list of chemical elements.[76] Mann and Twiss's *Physics* (1906) relieved themselves of some of the risk of committing the tenuous understanding of x-rays to print by noting that "so much has been written in the magazines about these rays, and their applications to surgery have brought them so prominently before the public, that we need mention only some of their most marked characteristics."[77] Ames's *Text-Book of General Physics for High Schools and Colleges* (1904) dispatched with Roentgen rays, canal rays, other discharges in vacua, radioactivity, electrons, and hypotheses of atomic structure in eight pages, making it a relatively verbose contender for its time.[78] In their first two decades, however, the physical properties of the rays were too nebulous for most textbook authors to grasp them safely, and so other means of addressing the subject were required.

Consequently, a major element in most textbooks' presentation of ionizing radiation, and especially of radioactivity, was biography. This was the case even when the text as a whole did not introduce concepts with capsule bios or accounts of scientists' work. Biographical explications of the rays was frequent in early texts, and still more prevalent toward the later portion of the period, in some cases accounting for most of the content presented on the subject. "What a story!" began the biography of Curie that opened the final unit of Biddle and Bush's *Dynamic Chemistry* (1937), switching abruptly to informal narrative after seven hundred pages of didactic prose.[79] In textbooks, that story typically centered on the extraction of radium from pitchblende. The title of §747 of *Modern Chemistry*, "How Was Radium Discovered?" was answered by the title of §748: "The Prize Is Earned by Hard Labor."[80]

The intent of these biographies was to create in students a sense of personal empathy with the heroic scientists that were presented to them, the better to inculcate in them the values and habits that those scientists were meant to represent. The textbooks' presentation of biographies of Curie, Roentgen, Edison, and other investigators of radiant energy served as an opportunity to present a moral lesson about science, especially the values of hard work, self-discipline, and a prepared mind. This was sometimes presented in starkly moralizing tones. *Chemistry and You* gave its treatment of the rays the title "A Family Tree"—the family referring both to chemical families and the close working relationship it implied for the scientists it discussed—and the subtitle "How an observation, an accident, and an error led to the discovery of a series of radioactive elements." The observation was Crookes's discovery of cathode rays; the accident was Roentgen's discovery of x-rays, which "fortunately for all of us . . . occurred to a keen observer with a scientific insight and experimental ability." The error was Becquerel's hypothesis that fluorescent materials emitted x-rays, all of which taken together culminated in the heroic struggles of M. and Mme. Curie, told in the traditional narrative.[81]

Textbooks made a virtue of the chaos into which x-rays and radioactivity had thrown the physical science community by favorably comparing their discoverers to a straw-man version of the prior generation. "About the end of the nineteenth century many self-satisfied scientists were grumbling, 'All the great discoveries have been made; if we had only lived sooner,'" began a 1944 book's biographically oriented treatment of radioactivity in which Roentgen, Becquerel, and the Curies were demonstrated to be made of sterner stuff.[82] Beneath a schematic graph showing the exponential increase in the "rate of significant discoveries . . . since the rebirth of the scientific method by Galileo," the introduction to a 1936 general science text referenced Albert Michelson's notorious 1894 claim that nothing remained to be done in physics but calculate more decimal places. What gave the lie to that statement, the textbook held, was specifically "the discovery of photo-electricity, x-rays, radio, and the study of electrical discharges."[83] Overton Luhr's *Physics Tells Why* (1943) also invoked Michelson, and likewise noted that "immediately afterwards, there followed in rapid succession the discovery of such marvels as x-rays, radioactivity, artificial transmutation, and atom smashing." The choice of the novel energies to illustrate this point (made in other texts without specific reference to Michelson) is not solely a function of the fact that they "came next," but also of the fact that they retained a sense of potentiality about them. Having set the stage with a renunciation of Michelson, *Physics Tells Why* proceeded to conclude with a list of innovations in the physical sciences its authors saw for the coming decades, that included atomic power and ultra-intense x-ray weapons for use in warfare.[84]

Most textbooks presented students with the image of a dynamic, closely linked, and unified scientific profession, in implicit contradistinction to the individual geniuses working in isolation that had preceded the modern age. The whitewashed account in Cottler and Jaffe's biographically oriented text *Heroes of Science* (1931) has Crookes handing off his tubes to Roentgen, whose rays inspired Becquerel, who "rushed off to tell his friends, Professor and Madame Curie" about radioactivity, whose collaboration ultimately yielded radium. This ad hoc team of scientists, who collectively succeed in demonstrating the transmutation of elements, is contrasted in *Heroes* *of Science* with an anonymous thirteenth-century alchemist working alone, in a "gloomy cell," toward the same goal.[85]

Textbooks used the alchemical metaphor liberally, a bright and shining refutation of the stock character of the pre-Galilean ignorant that was at the same time an unambiguous brief on behalf of the potential of science, fraught with excitement and meant to tantalize students into acculturation. In this one regard, textbooks adopted the techniques of contemporary popularizers by depicting modern ray-investigators as wizardly, but only them: Becquerel or Rutherford might be called a "modern alchemist," but never Lavoisier or Priestley. "The alchemists of old endeavored to transform one element into another; they failed," Black and Conant's *Practical Chemistry* (1920) noted under its "Further Study" heading at the end of the chapter on radium and radioactivity. "How does 'modern alchemy' differ from the old?"[86] The answer, presented with no great subtlety in most textbooks, was that "new alchemists" were correct and others were not. Greer and Bennett's *Chemistry for Boys and Girls* makes neatly explicit the subtext that attended the new versus old dichotomy that the textbooks favored. After the failure of the old alchemists of the Middle Ages, when

> men came to know more about science, they believed that the alchemists' attempts to change base metals into gold was futile. . . . For more than a century, this idea prevailed among scientists. Recently, however, some of the discoveries regarding an interesting substance classed as an element and known as radium are placing the efforts of the alchemists in a somewhat new light.[87]

The "modern alchemists," then, who detected transmutation were superior in perception not only to their medieval analogues, but to the old guard of science as well—an agreeably teleological understanding of science for a school text.

* * *

School science textbooks had proliferated in the early twentieth century because of the confluence of a boom in high school enrollment and the increasing centrality of science to the curriculum. Not all reading on the subject was so compulsory, however. The first half century of radiation and radioactivity coincided with a renaissance in book-length popularizations of scientific subjects. The unprecedented attention that x-rays and radium received had prompted luminaries of the new sciences like Frederick Soddy, Oliver Lodge, Rayleigh, William Ramsay, and others to reach out to lay audiences. It also attracted the attention of the professional popularizers, whose books took the field as the scientists gradually ceded it by the beginning of the 1920s. This latter class of books were frequently organized as discrete essays of chapter length on specific topics that could be read independently, and authors had great discretion in what material to present. Most engaged enthusiastically with the novel radiations, a subject whose fluidity among professional scientists made it a difficult subject on which to speak authoritatively, but naturally the unusual excitement it had aroused in the general public made it an attractive topic.

Who read these books? Ronald Tobey has called the popularization of science at the turn of the twentieth century a "literary and genteel indulgence."[88] Most of the first generation of popular science books were written in fairly rarefied language, and often assumed some fairly sophisticated knowledge on the part of their readers with respect to the subject at hand. Books on radio, medicine, aviation, and electricity existed, but generally made no effort to appeal to non-enthusiasts with explanations of basic concepts, illustrations, or engaging writing styles. Rather, the model was of the respectable repository of knowledge that might furnish a home library, as much reference as recreation.

However, the market expanded considerably in the 1920s and beyond, thanks to a sudden eruption in demand for popularizations, mostly among the urban middle class. This spike in interest had many roots, chief among them an increasingly literate and educated populace that had more leisure time and more reason to wonder about the impact of science on their lives. Accordingly, authors adopted a reportorial style that mixed anecdotes, casual language, and biography. The perfectly authoritative tone preferred by scientists in their outreach to the lay public was sacrificed in favor of accessibility.[89]

Popularizations about radiation and radioactivity were idiosyncratic. From the start, the public enthusiasm for them gave no indication of being constrained by class boundaries or a predisposition to "genteel indulgences." Virtually all books on the topic remarked on the inordinate curiosity that had greeted the rays, and the pressing need for a straightforward accounting of them in everyday terms. Wiltshire and Pullins's *X-Rays Past and Present* (1927), for example, opened its preface with an apology for its "somewhat alarming" and intimidating chapter headings, which might frighten away the "interested and enquiring layman," but hastened to reassure of their intent to explain the x-rays in “non-technical language . . . which imposes no necessity for a preliminary scientific training.”[90]

Most of the leading lights of research into the novel energies had engaged in some form of public outreach, occasionally at book length. It was not until rather later, in the 1930s, that the field was left essentially clear for professional science writers. When professional popularizers did take the lead in depicting radiation and radioactivity to those laypersons who elected to know more, they were scarcely less partisan in their advocacy on behalf of the “new sciences” than the new scientists themselves had been: those writing about x-rays and radioactivity in this latter phase included Edwin Slosson, David Dietz, and Waldemar Kaempffert—all charter members of the National Association of Science Writers, an organization chartered to improve the quality of science coverage by improving relationships with scientists themselves.[91] X-rays and radium were, for these authors, important weapons in science’s fight for the hearts and minds of the general public.

Professional popularizers rarely addressed the question of what x-rays and radioactivity were “good for.” In part, this was an attempt to distinguish their books from what they regarded as the sad state of affairs with respect to the rays in the press. “Popular articles, with their pretty pictures of protons and electrons, are all too likely to leave the reader either muddled or uninformed,” author James Kendall noted with displeasure.[92] Kendall was an academic chemist, and by virtue of his profession had probably acquired its endemic antipathy for the press’ treatment of science. Others developed it by empathy: Robert Kennedy Duncan, who castigated the “pseudo-science of the magazines, which is arranged chiefly for dramatic effect rather than for accurate exposition,” dedicated his book on *The New Knowledge* to “these masters of science:” Becquerel, the Curies, Rutherford, Lodge, Wilson, and other notables of the investigation of radioactivity. Having introduced that cast of characters, Duncan apologized for himself in advance “if any portion of this book seems a little too enthusiastic.”[93]

As often, the public itself—the portion of it that did not read edifying books, at least—came in for chiding: Hampson addressed his treatise on radium to “the people—the more thoughtful section of course—that they may obtain some more systematic and intelligible information about radium than could be gathered from frequent disconnected and sensational articles in the daily press, or smart and ‘snappy’ contributions to the monthly magazines.”[94] The effect of such statements, magnified all the more when they came from highly regarded scientists like Kendall, Soddy, or Oliver Lodge, was to construct an identity for the rays as rarefied subjects. Lodge, for example, wrote that he had been moved to write on radiation by a remark by J. J. Thomson that the public was hungry for intelligible works on the subject, in spite of there being "very little popular knowledge or understanding of the matter" at present.[95]

For all their outward distress at the antics of exaggerating or misinterpreting reporters, however, ray-popularizers were not above their own particular brand of sensationalism. Often this took the form of one-upmanship in depictions of the magnitude of intra-atomic energy. Indeed, because the liberation of nuclear energy was the immediate concern of many popular treatments (and implicit in the discussions of most others) such images were ubiquitous. Watson Davis, unable to choose just one, gave his readers a laundry list:

> Here are some of the startling possibilities, if and when science finds a way to annihilate matter and utilize the constitutional or sub-atomic energy of matter that would be released:
>
> A breath of air would operate a powerful airplane for a year continuously.
>
> A handful of snow would heat a large apartment house for a year.
>
> The pasteboard in a small railroad ticket would run a heavy passenger train several times around the globe.
>
> A teacup of water would supply the power of a great generating station of 100,000 kilowatts capacity for a year.
>
> If lead could be changed into gold, the value of the energy released would exceed enormously the value of the gold produced.[96]

The abundance of wordplay with the energies locked away in the atom has much to do with the fact that the popularizers showed a great deal more reticence than textbooks, or for that matter most print sources of information about the rays, to conjure with their practical applications. The surprisingly few occasions on which the fruits of research on radioactivity were addressed often took the form of abstractions, as with Carl Chase's notably restrained remark in *Frontiers of Science* (1936) upon the significance of the new process of artificial transmutation: "One can feel sure that many important and exciting discoveries will result from this new stimulation to investigation in the field of atomic and nuclear physics."[97] Others were more openly scornful: Waldemar Kaempffert was pleased that out of atom-smashing, "the intellectual effort to explain what the atom is, comes a new, profound, and stirring conception of the universe and our place in it," that incidentally smashed "scientific and philosophical self-satisfaction" in the process. But turning his gaze to practical applications and those who considered it "a possible savior of our culture," he pointedly noted Robert Millikan's barb that as for nuclear power, "There is not enough radium at our disposal to run our popcorn roasters."[98]

Viewed in light of the popularizers' near-total embargo on discussions of the contemporary, actual uses of radiation and radioactivity, the enthusiasm that attended speculations about atomic energy is easier to understand. Unencumbered by actuality, it could appeal to audiences with its potential, and in the process allow the author to situate the new breed of atomic scientists at the center of the story. Benjamin Gruenberg, a textbook author and social commentator, argued in 1935 that such speculation in science popularizations was a "rich source of aesthetic satisfaction" precisely because "the pursuit of the not-yet-known . . . also meets a human need quite as truly as do other forms of play" in ways that already realized technologies might not.[99] Radium had killed people; limitless atomic energy had not, yet. Consequently, it was a safe space for conjecture: atomic energy in 1925 was nothing more than the slight warmth radiated by concentrated radioisotopes, and even after the disintegration of lithium atoms had been achieved in 1932 it had no existence outside the laboratory (or immediate prospects to leave it, as far as the public knew).

Popularizers only occasionally discussed more recently discovered ray-phenomena, preferring to keep to the flurry of discoveries made at the close of the nineteenth century. David Dietz' *Story of Science*, first published in 1931, is representative in that the portion of the story touching the new energies ended in 1901 with Soddy and Rutherford at work on transmutation.[100] There were some exceptions: popular books in the 1930s occasionally addressed the work of Cockroft and Watson in artificial transmutation, or the Joliot-Curies's work on induced radioactivity. But the historical mode was more common in these treatments, and was adopted for the same purposes as it was in schoolbooks: its compelling narrative. This was contrary to the general practice of popularizations of the period, which had found history of science to be unpopular with the public.[101] But the evangelical potential of the stories about Roentgen, Becquerel, and the Curies was too great to ignore.

Rays in Fiction and Poetry

Considering the amount of space in textbook and pop science accounts of radiation given over to speculation about its eventual applications, it is hardly surprising that wondrous and mysterious rays became a staple of the era's science fiction, too. Thanks to an voluble and activist readership, the pulp magazines and dime novels that conjured with radiation and radioactivity did so in ways that far more directly flattered their audiences' expectations. As science fiction expanded beyond the hardback novels of Jules Verne and H. G. Wells—the so-called gaslight era of technological romances—and into a wider readership, fandom became a collective and participatory endeavor, with communities of aficionados linked by private clubs and mailing lists. A web of amateur-produced and privately distributed "fanzines" had come into being by the early 1930s, and buttressed the pulps and the book publishers.[102] Aspirant writers (or slumming professional authors), and amateur reviewers formed personal connections through the letters pages of the pulp magazines or local science fiction clubs, and the mimeographed and hand-addressed fanzines were the result.[103] They were notoriously ephemeral, often lasting only a single issue, but allowed for a free and frank exchange of ideas and stories among the genre's most enthusiastic fans: in its second anniversary issue, the *Science Fiction Critic* felt free to refer to itself as "The Oldest And Most Widely Read Amateur Periodical In The Field Of Imaginative Fiction."[104] Often the fanzines were the organs of local science fiction clubs, while others were dedicated to critical reviews of the established magazines, insider gossip from the genre press, or committed to the popularization of real science through an outreach to fiction readers.[105]

Fanzine editors were evangelical, and the fanzines themselves were active and critical participants in earnest discussions within the science fiction community about atoms and rays—critiquing not only individual stories but the larger import of nuclear energies in fiction and in real life, and in frank and unguarded terms. Contributing to a fanzine discussion on the favorite topic of whether authors were abusing the use of radiant energy as a plot convenience, one fan opined that

> it is true that the subject of rays has been grossly overdone in science fiction. Still, there is the opposite extreme—that of denouncing rays entirely—which is bad. Rays—light, heat waves, X-rays, and so forth—are as fundamental in the universe as matter itself. You can't get away from them, and they do marvelous things. . . . And their further use, in our science, I believe, is quite near.[106]

Marvelous things done by marvelous rays were a central concern of fanzine discussions, and professional editors and writers took notice.

Because of the economically precarious nature of the genre publishing industry—which relied on high volume, exploitation of formula, and repeat business—sensitivity to reader response was extraordinary. Language, attitudes, styles, science content, plots, and character types were all subjected to the acid test of reader satisfaction, and the process was made explicit and transparent on the pages of the pulps and fanzines. Readers repeatedly demanded more science content—both in the stories themselves, and as standalone nonfiction articles. Because so many stories featured atomic power or exotic radiations, these were popular subjects for discussion in the various "science fact" columns that every pulp (and many fanzines) published.[107] While the quality of discussion that ensued from these articles was not always uniformly high, the volume of discussion was. Some were more scientifically savvy than others, but editors printed them because each such installment would all but guarantee a response, thereby increasing reader investment in the magazine while generating column inches at no cost.

The hunger for information about rays and the strange energies bound up in radioactive elements was palpable in the readers' columns of the pulps. One suggested that to better to distinguish between established science and extrapolation, the former should be put in italics or otherwise set off from the fictional text. (The editors demurred.) But most letters to the editor about ray-content were sharply worded criticisms deployed when readers felt that an author's factual extrapolation had gone awry. The specifics of those critiques give some indication of how subtle the boundaries between acceptable and unacceptable reimaginings of atomic energies could be, and how closely those boundaries were guarded by the readers:

> Let me point out a few of the more obvious faults contained in this crude attempt at a science fiction story. The author has borrowed the old themes of science fictionists, wherein the scientist creates a ray capable of changing one element into another by destroying some of the electrons of the atoms of matter subjected to its influence. Nothing wrong so far. But when he changes a leg of marble into one of flesh and blood, the story becomes absurd. Kindly give me your attention while I point out to you just how ridiculous this is.

Science Wonder Stories reader Burris Cunningham proceeded to do just that, and concluded that "the fact that I, whose education in science does not exceed that obtainable in the ordinary high school, should be able to pick flaws in it, shows just how poor this story is."[108]

Cunningham was angry at having been led partway down the garden path by a technically flawed story, not because he found the notion of vitalizing rays in and of itself offensive or implausible. Several other readers published that month felt the same way, necessitating an exhaustive defense from the author of the story.[109]

Atomic energies were well adapted to this process, and the enthusiasm and pervasiveness with which they were adopted by authors makes clear the depth of fascination with them. The first issue of *Science Wonder Stories* in 1929 is exemplary here: four stories out of five engage in various kinds of ray-talk. In its inaugural story, "The Reign of the Ray," an inventor likens his newly discovered rays to Millikan's cosmic rays and exults, "What would a medieval alchemist give to have one of these Coolidge tubes! The Philosopher's Stone realized! Imagine reducing a gas to an amorphous solid, simply by unseen emanations, and imagine making a stone glow with light."[110] In "Warriors of Space," a green ray wielded by aliens "seemed to have the power to reduce to nothing any substance that it touched."[111] "The Marble Virgin," which had found such disfavor with reader Cunningham, has a stone statue transmuted into flesh by a mad scientist's lead-coated, glowing machine.[112] An entire expedition of scientists, some madder than others, is imperiled in "The Making of Misty Isle," when a "thorium-oxide radioactive explosive" triggers massive geological instability.[113] Even the awardees in an essay contest on the theme "What Science Fiction Means To Me" found occasion to reference radium-driven spaceships and "whirling worlds within the atom."[114]

The only restriction on atomic forces, as understood by their literary interpreters, was that they must be hyperbolic. Even when the futuristic setting of a story dictated that exotic rays or substances were commonplace, with grams of thorium fueling the family airship and Z-ray telepathy the order of the day, the reverence with which amateur and professional authors alike treated those phenomena remained apparent. Except, occasionally, when radium was used for luminescence in stories (as, of course, it was in actual twentieth-century life, too), nuclear emanations were almost never deployed to do an ordinary job in an ordinary fashion—only to accomplish impossible tasks with ease, or mundane ones in an extraordinary fashion. To gratify their readers' sense that strange and fantastic things were just over the horizon, they bathed the strange and fantastic things in their stories in the pale green glow of nuclear decay and Crookes tubes. The net effect was to reinforce the almost mystical associations that clung to these scientific terms. Airships to Saturn were all well and good;

Radium Airships of Saturn made the cover of *Amazing Stories.*[115] Ray-talk borrowed plausibility for otherwise fantastical happenings against the now-enormous credit of the science of the near future—and readers' growing awareness of penetrating rays and enormous intra-atomic energies made them quite willing to approve the loan.

Radium extrapolations and ray-talk, then, served the commercial needs of publishers. But they also served the readers' need for a safe haven from "science-fact"—a rhetorical space in which legitimate fears about atomic energies could be explored and assuaged, while at the same time optimism about the same could be given free rein without having to endure the agonizing wait for the promised fruits. Atomic energies were hardly the only workhorse of science fiction, but no other idée fixe received such richly detailed elaboration. Space travel was ubiquitous (and, latterly, usually powered by radium or the fictional equivalent) but while its technical points were sometimes debated in the readers' forums, it was seldom treated as broadly transformative and almost never given the kind of reflective analysis that radiations were. Just the same is true for the fourth spatial dimension, another standard of the genre. Even eugenics, a hotly debated topic in and out of fan forums and a favorite theme in the stories, was generally treated only as a plot device—a mechanism by which to move the story along.

The stories that explore atomic energies, however, form a rich pantheon of interconnected understandings, in which various meanings and images were tested, and in which every extant fear or hope about the phenomena had a literary manifestation. X-rays and radioactivity had seemed like something out of science fiction at the start, energies that were only partially explicable, only occasionally tangible, and only statistically predictable. A phenomenon that seemed only half real was ideally suited for fictional treatment, and in turn it made the fiction seem tantalizingly (or ominously) close to reality. New narratives about the atom—in effect, a brand-new nuclear mythology—came into existence as a result of the constant retelling and retooling of stories about radium and rays.

As the first story to envision nuclear warfare, H. G. Wells's *The World Set Free* (1914) has primacy of place in any discussion about atomic-themed fiction. It famously inspired Leo Szilard to think seriously about the possibility of nuclear weapons, and coined the phrase "atomic bomb."[116] The last of a series of prophetic works by Wells about the future of warfare—*The Land Ironclads* (1904) foresaw armored mechanical vehicles like tanks, while *The War in the Air* (1907) predicted exactly what its title suggests—*The World Set Free* was itself directly inspired by Soddy's *Interpretations of Radium*, to which it was dedicated. Like many others, Wells had been fascinated by Soddy's discussions of radium-driven battleships and quart bottles of uranium compounds that held the energy of a million tons of coal. Wells's preface to the 1921 edition makes clear that, in light of the impending war with Germany, the release of such energies had taken on a threatening cast in his mind.[117]

The result was a future-war story of the type he was already well known for, but with a nod to his sympathies for the pacifist world socialism movement: a war fought with explosives of the type Soddy imagined would be so horrendous that any surviving peoples would be compelled to put aside their national prejudices once and for all, or face total destruction. Where giant rail-tanks or Martian tripods had not scared Wells's protagonists into world government, atomic energies did the trick. The hope, sometimes more clearly expressed than others, that a modern war fought with the tools of modern science would be too horrific to contemplate (more than once, anyway), was not unique to Wells or the science fiction authors. After the "chemists' war," fought with mustard gas and high explosive artillery that brought "shell-shock" into the lexicon, the First World War was optimistically referred to as "the war to end all wars." The hyperbolic tendencies of speculative fiction, whose weapons were (of dramatic necessity) still worse, nourished this hope in dozens of novels and short stories.

That said, *The World Set Free* was more of a pioneer than a leader: while it introduced the image of the catastrophic atomic explosion into the nascent genre (just as his *War of the Worlds* had introduced the notion of the burning ray), and the sickness from radioactive contamination that might result, it did little to influence the portrayal of atomic energies in the stories that followed. While the book was well-reviewed on its first printing in early 1914, it did not attract much public attention until hostilities commenced in Europe in August, when it became the subject of conversation and an advertising campaign more for its prediction of a pan-European war than its invocation of bombs that worked on a radioactive principle.[118] To be sure, its depiction of a world too weary from one apocalyptic war to ever fight another was imitated—even as the stories appearing in the pulps once again became increasingly militant with the rise of Hitler's Germany.[119] But militancy notwithstanding, bombs remained only one potential application of nuclear energies, and not the one that readers were most interested in. Science fiction magazines seldom mentioned *The World Set Free*, either in commentary or in letters columns, and never reprinted it—unlike many other stories by Wells, Verne, Edgar Allen Poe, and other eminences from their generation of speculative fiction.

Martha Bartter has noted that "awful warning" stories are a staple of the genre and that Wells's work should be understood alongside other stories that use the "magic word" of radioactivity not as a portent of doom, but as a talisman against war itself.[120] In Arthur Train and Robert Wood's *The Man Who Rocked the Earth* (1915), the mysterious inventor of a monstrous death ray that burns flesh and vaporizes ships blackmails the belligerents of the world into giving up their armed forces; in Hollis Godfrey's *The Man Who Ended War* (1908), an unnamed radioactive substance is used in almost precisely the same way to the same effect.[121] In all three stories—all of which were published during the initial flush of popular radium mania—an "atomic" or "radio-active" weapon is merely an arbitrarily powerful one, a MacGuffin for stories that are more about war itself. For all the obvious apocalyptic potential of atomic bombs and death rays, prewar audiences found other aspects of radiation and radioactivity more compelling.

For example, their use in making money. "6 gr. Radium Salts = $600,000.00," read the prologue to Edith MacVane's "The Radium Robbers." "This is the equation that projected Fanny Gordon into one of the most amazing and dangerous adventures of her career."[122] Its monetary value projected countless other heroes and heroines to their own adventures, too. The association between radium and wealth was so strong, in fact, that authors quickly moved past merely introducing a rich vein of pitchblende as a plot device. George Allen England's 1916 novel *The Golden Blight* is a fusion of the ray-wealth idea with the alchemical notions of corruption and renewal. A scientist brings the capitalist world to a standstill with a mysterious "zeta-ray" that reduces gold everywhere to ash. Explaining his accomplishment to the financier who becomes his chief antagonist, he sets the scene for England's audience this way:

> Where other men have courted womankind, I've courted X-rays, N-rays, cathode-rays, Hertzian waves, wireless projection, and all that sort of thing. The Curies, Becquerel, Lodge, Crookes, and the rest, have nothing to teach me. I've begun where they've left off. The human race, in regard to radio-activity, stands today just about where it stood in regard to fire, when only a few of our anthropoid ancestors knew how to make it—when it was all a red, roaring mystery, heaven-sent, to the hairy hordes that roamed the jungles. But I—well—I understand the matter. Yes, quite fully. I can produce strange forces, and direct them."[123]

Eventually the world's gold supply is restored, but not before society is transformed, purged of its addiction to gold and freed from the need to make war in order to obtain it. (England was an active socialist and *The Golden Blight* was intended as a vehicle for his politics.) With its theme of wealth destruction (however temporary), *The Golden Blight* was the inverse of a fairly common trope in which radium or a novel ray stands in for the Midas touch, but all the members of this class served to reinforce the message that the surpassingly rare and powerful element radium stood in the same sort of hyperbolic relationship to gold as gold did to the base metals.[124]

Another evocative fusion of these new mythological elements is found in Albert Dorrington's novel *The Radium Terrors* (1912), which puts in stark dramatic context the real-life rumors that radium was being kept artificially scarce by medical or mining consortia.[125] A mad scientist uses concealed radium to blind wealthy marks, then profits when they attend a "Radium Institute" under his control for a cure.[126] Like many accounts of radium's power, fictional and otherwise, it depicts that energy as finely balanced between beneficial and harmful—as a scalpel whose application can be miraculous or disastrous, depending on the skill and intent of the person wielding it. But its immense popularity—it went through at least a dozen reprintings as a standalone novel—derives from the fact that it resonated with a reading public who found the idea of a shadowy conspiracy of radium profiteers all too believable.

Finally, and perhaps most significantly, science fiction provided a means by which anxieties about nuclear explosives, immodestly penetrating rays, x-ray burns, unstable atomic ontologies, radium toxicity, and all the other lurking dangers of radiation could be soothed through humor. These were frightening enough to many without the stimulus of science fiction; for pulp readers who saw the world blown to bits by radium on a monthly basis, the occasional comic relief was mandatory. Often this took the form of writers lampooning their own overuse of ray-talk. John Campbell, one of the more highly regarded pulp authors, penned a story called "Space Rays" that was such an accurate parody of the standard ray-based story that editor Hugo Gernsback felt compelled to explain Campbell's intent in an editor's note. Decrying "implausible" stories that blurred the line between science fiction proper and mere fantasy, Gernsback assures his readers that Campbell

> has no doubt realized this state of affairs and has proceeded in an earnest way to burlesque some of our rash authors to whom plausibility

> and possible science mean nothing. He pulls, magician-like, all sorts of impossible rays from his silk hat, much as a magician extracts rabbits. There is no situation that cannot easily be overcome by some sort of preposterous scientific—(as he terms it)—gimmick. . . . If he has left out any colored rays, or any magical rays that could not immediately perform certain miraculous wonders, we are not aware of this shortcoming in his story.
>
> I have gone to this length to preach a sermon in the hope that misguided authors will see the light, and hereafter stick to science as it is known, or as it may reasonably develop in the future.[127]

Campbell, who would go on to edit *Astounding* and was nearly Gernsback's peer in the genre's hierarchy, was critiquing bad writing, not a misappropriation of atomic themes in particular. But in attempting to stem the tide of stories where arbitrarily miraculous rays were called upon to wrap up any untidy plot points, Campbell was explicitly addressing the fact that ray-talk served different purposes for authors than it did for readers, and that the readers' need to engage constructively with fictional rays that bore a resemblance to actual radiations must win out in the end.

* * *

Science fiction, like other forms of genre literature, was regarded by most educated Americans as, at best, a middlebrow indulgence. If it furthered and refined the discourse about radiation, it did so primarily to a typical reader who was, in the words of publisher Lester del Rey, "white, male, and probably somewhat more intelligent than the general level of the population, though hardly the genius he liked to believe himself."[128] Nevertheless, the particular appeal that futuristic energies had for science fiction authors did mean that contemplation of such things was limited to pulps' audience. The rich connotative palette that radiation also made it a favorite of poets. As with advertising copy (which, as an art form, by the end of the first half century of radiation arguably had the greater claim to formal exactness), wordsmiths used the terminology of the novel energies as an all-purpose superlative. Just as radium stove polish was the best possible stove polish, a "Man of Radium" was the best of all men, better than men of iron, and so a partisan newspaper ran some verses under that heading in tribute to Theodore Roosevelt: "In all he does with strength unflagged / He strikes amazement dumb— / A pillared flame by night and day, / This Man of Radium!"[129] The four-stanza poem ran on a full page of newsprint, with garish ray imagery adorning a caricature of Roosevelt. For all its lack of verbal or visual subtlety, the piece reinscribes radium's connotations of energy even as it instructs those not yet fully acquainted with the element by providing a metaphorical cognate in the person of the President.

Occasionally, that instruction was explicit: the quatrains in "The Song of Radioactivity" (1911) form a whimsical yet deliberately pedagogical survey—a refresher course in verse—that lists the radioactive elements, depicts the use of a gold-leaf electroscope, reviews atomic ontology from Lucretius to Dalton, and reiterates the contemporary belief held by some physicists that all atoms were fundamentally unstable and therefore radioactive, though decaying at an imperceptibly slow rate.[130] Whimsical and rhyming, and probably commissioned just for the issue of *Popular Mechanics* in which it appeared, it was not "serious poetry," nor did it engage with the deep symbolism that radioactivity had acquired in the public mind. Instead, it represented the phenomenon as something to be toyed with intellectually, a delight for the imagination that was somehow also of much deeper significance than the magazine's usual fare about new alloys or improved radio antennae.

As the years passed, the radiation that was captured in ephemeral poems like the ones above had remained a fixture in news accounts and popular culture, and entered in to the school curriculum. Accordingly, later poetical conjuring with radioactivity took for granted that its audience would understand the reference, and in detail. Mina Loy's 1924 elegy "Gertrude Stein" called its subject the "Curie / of the laboratory / of vocabulary," referencing in the following lines the extraordinary labor she undertook to isolate the "radium of the word."[131] The poem is a sort of crab canon of tribute, with the tools of Curie and Stein's respective trades juxtaposed, but significant for how easily the referents to Curie's work are deployed. Loy knew, as did most Americans, the circumstances of Curie's laboratory, and enough about the properties of the element for the phrase "radium of the word" to be properly evocative.

Typically, poems about radiant energy celebrated the era's ostentatiously scientific zeitgeist. At the conclusion of a lengthy meditation in verse on radium, which "baffles all the wisdom of the wise / and holds perchance the secret of the world," R. H. Law reflects on the glimpse that radium, "the stuff wherefrom the stars are spun," had given of the deep and dark complexity that underlay the natural world. Despairing of the ignorance that that tiny bit of knowledge has revealed—"in vain with glimmering torch we peep and peer"—he concludes:

> *But moments are there when, we know not how,*
> *The soul is quickened to a keener sight;*
> *She seems in holy presences to bow*
> *And quench her life-thirst at the sacred springs.*
> *Too brief her sojourn in that airy height!*
> *Too soon she wearies of her lonely flight*
> *And nestles on the earth with folded wings.*[132]

The poem, "Radium" (1904) ran in *Living Age*, a large-circulation magazine, and reflected three widely held perspectives on the novel energies. It asserted that they portended disaster (at least in the short term) for the scientific establishment whose models they cast down, it attested that they were of unutterable significance as a tantalizing glimpse at the real workings of creation, and it celebrated the euphoria of scientific discovery that had seized many Americans who could experience it only indirectly. In all three, it anticipated the publication of *The Education of Henry Adams* by several years, but many others gave voice to the same sentiments.

Radiation's Risks and Rewards in the Press

The immediate practical implications of contemporary science and technology were everywhere apparent in the early twentieth century, and radiation and radioactivity were exalted in science books, newspapers, and wonder shows largely for the good they could do in the here and now. Literary conjurings with them, by contrast, tended to focus on the deeper relationships between people and nature, or—as a consequence of the fame that attended many of the early researchers into nuclear emanations—specific persons and nature. Marie Curie, while on her second trip to the United States in 1929, journeyed to remote Canton, New York, to dedicate the new chemistry building. A tributary sonnet was written for the occasion by a Charles Kelsey Gaines, a member of the physics faculty. It concluded with a couplet, "Let all the ghosts of alchemy bow down / While on this woman's brow we set the crown," that might have embarrassed Curie had she not had so long to grow accustomed to the burdens of fame.[133] Her personal celebrity had been augmented not only by 20 years worth of glowing references in magazine articles and radium-tonic pamphlets, but also her role in bringing to fruition the mobile battlefield x-ray units that came to be known as "petite Curies." Her 1921 visit was arranged so that Curie might receive a gift of one gram of the radium for her own research purposes, courtesy of the recently established American radium refining industry and a lengthy list of underwriters.[134]

Biographer Susan Quinn has noted that this presentation of affairs required Curie to be at least somewhat complicit in playing the role she was assigned—modest, unassuming, impoverished, and the tireless worker deserving of the best tools for her work.[135] It also required her to present herself for inspection to a long series of audiences, most of whom had probably seen one or two radium wonder shows before. The fund drive for the gram was oversubscribed by $50,000 and lecture halls were packed full to such an extent that Curie had to resort to wearing a bandage on her hand to protect it from the cumulative effect of handshakes.[136] Curie was not an electrifying speaker: when she spoke at all, and especially when she didn't, observers tended to describe her as shy or modest or soft-spoken. She was not, in other words, a William Hammer. She was even upstaged by her daughter Eve, at the time an outgoing 16-year-old who charmed socialites at parties in her mother's stead, and who later gave popular lectures on radium herself.[137]

At the outset of her tour, President Harding ceremonially presented Curie with a facsimile the gram. Harding's words on that occasion give some insight into the layman's perspective. Curie's work as a scientist, he noted, was to unravel the question of where radioactive energy came from, but to his mind

> the question suggested an answer which is doubtless hopelessly unscientific. I have liked to believe in an analogy between the spiritual and the physical world. I have been very sure that that which I may call the radio-active soul, or spirit, or intellect—call it what you choose—must first gather to itself, from its surroundings, the power that it afterwards radiates in beneficence to those near it. I believe it is the sum of many inspirations, borne in on great souls, which enables them to warm, to scintillate, to radiate, to illumine and serve those about them. I am so sure of this explanation for the radio-active personality that I feel somehow a conviction that science will one day establish a like explanation for radioactivity among inanimate substances.

If Curie objected to this sort of casual vitalism, she was too diplomatic to say so in her remarks. In any event, she could hardly have found it unusual, given the balance of her experiences touring the country. She had addressed the International Federation of University Women in Carnegie Hall, was the subject of a convocation at the University of Pittsburgh, dedicated the new chemistry building at remote St. Lawrence University, and donated one of her husband's piezoelectric meters to the College of Physicians of Philadelphia. At each of these, and dozens others besides, she consented to give an address on radium, and her surviving lecture notes suggest that each time she gamely revisited the basic principles of radioactivity at a level suitable for the laity.

Curie's public appearances, which by all accounts she dreaded, were the price she paid for actual quantities of radium. But other scientists were learning to leverage the collected weight of public interest against obstacles in their own professional lives. Robert Millikan, whose affinity for the spotlight alternately amused and annoyed his physicist colleagues, used the occasion of Curie's first American visit to present a new kind of origin story for radium. During the first popular frenzies, the scientists who worked with the novel energies had been presented as revolutionaries. Now that work involving radiation and atomic energies was squarely in the mainstream, Millikan preferred to depict the discovery of radioactivity as modern man's richly deserved reward for centuries of patient toil:

> Man-Of-War did not develop his marvelous speed in one generation. A dozen sires and dams contributed to that result, and in precisely the same way when Professor Jean [*sic*] Becquerel, a professor of physics in Paris, discovered this new, extraordinary property which some matter possessed and which was named radio-activity, that discovery was sired by one made a year before by Roentgen, and Roentgen's was sired by Leonard's, and Leonard's by Hertz' and Hertz' by Maxwell's, and Maxwell's by Faraday's, and Faraday's by Erskine's, and Erskine's by Volta's and Volta's by Franklin's, and so on without limit. And the point I want to call your attention to now is that it is just as important for those who have given this gramme of radium to Madame Curie to have a vision that extends, not to this generation only, but to the generations that are to come a hundred, two hundred years ahead, and to begin to beget and train a pedigree of scientific activity and scientific work that you are going to get the results in just the same way as a breeder of trotting and racing horses has worked through generation after generation.[138]

This came at the beginning of a speech for a general audience that included donors to the fund that endowed Curie's gift. Millikan's deft reframing of the "revolution" wrought by the discovery of x-rays and radium allowed him to present Curie's work—and by extension his and that of his peers and colleagues—as a moral necessity. He praised the donors in the audience not for their generosity, but for their support of a scientific establishment that was an inherently benevolent, civilizing force in the world. Forging the next link in the chain that joined Aristotle to Mme. Curie was essential "for the ultimate alleviation of the conditions of mankind and the betterment of life on this earth." When not speaking to Curie's benefactors, Millikan was openly dismissive of the idea that much would come of nuclear medicine or power generation, calling the latter a "completely unscientific Utopian dream, a childish bug-a-boo" in a 1928 speech. But he was also politically astute, in ways that many scientists were learning to be at the time, and he knew that there was no better way to burnish the reputation of the broader scientific establishment than to present its Curies and radiums as the rule rather than the exception.

* * *

By the time of Curie's second visit to the United States in 1929, she was in poor health, and there were already rumors that her long-term exposure to radium and other forms of radiation were to blame. Curie herself was dismissive of this speculation, but other professionals were taking such cautionary tales to heart. In fits and starts, radiologists and other x-ray-using physicians had been awakening to the cumulative danger posed by chronic irradiation, and the result was that more and more operators were trying to protect themselves. In spite of the fright that this protective gear sometimes gave patients, its wearers had tended toward a cavalier attitude toward irradiation from the start. The experimenters and early radiologists' fear of harm was dulled by familiarity and a distinct culture of martyrdom, in which individual insults to the flesh were treated as insignificant in the face of the potential benefits to medical science. The chemist William H. Greene captured the sentiments of many an early roentgenologist in a December 1896 letter to Elihu Thomson, who had badly, but intentionally, burned his little finger as a means of demonstrating to other x-ray experimenters the need for caution. Casting his expression of sympathy in a lighthearted tone, Greene asked, "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 that blast and wither but do not consume?"[139] This sort of gallows humor attended their discussions of their craft and the injuries and deaths that it was responsible for.

From time to time, word of the martyrs (the term is both their own and the one by which they were referred to) reached the ears of a broader audience. As late as 1921, the stories of the early radiological martyrs were current and effective at instilling fear in potential patients, the *Literary Digest* reported. "Some timid persons fear to allow a single radiogram to be taken" for fear of burns or worse—though the bulk of the article was given over to an unnamed expert who strove to reassure readers of the harmlessness of modern x-raying.[140] The dissemination of this cautionary language is itself probably more directly responsible for the decline of amateur x-ray photography than any other factor.

There had been a few high-profile mentions of radiation injuries during the crazes. Some of the earliest and most striking news of early x-ray martyrdom dealt with the slow and (characteristically) excruciating decline of Clarence Dally, a glassblower and one of Edison's principal laboratory assistants with respect to the x-rays. In August 1903, Edison announced that his own health had been negatively impacted by exposure to the rays six years before, causing poor digestion, lumps in his stomach, and eye strain. It was in this report that the public learned of Dally's suffering since that initial exposure, which had included a series of surgeries and amputations that had taken his left arm and was threatening his right. "I hope this [right] arm will not have to go, as his brother's did," Edison commented.[141] Dally's brother, seldom mentioned in initial or subsequent reports, was also a glassblower for Edison. The 1903 reports included shockingly brusque language from Edison on his changed attitude toward radiation: "Don't talk to me about X-rays. . . . I am afraid of them. I stopped experimenting with them two years ago, when I came near to losing my eyesight and Dally, my assistant practically lost the use of both of his arms. I am afraid of radium and polonium too, and I don't want to monkey with them."[142] The force that these words had must be measured not only against the degree to which Edison was regarded as an authority (unparalleled) but how unusual it was to have such negative sentiments expressed in print. Dally died the following year, despite optimism on the part of Edison and his doctors that he would rally, and was promptly labeled a martyr in front-page obituaries that left little to the imagination as to the sort of agony he had experienced as a result of his exposure.[143]

Dally's death was not quickly forgotten, either; his name remained a standby in a minor but recurring note in coverage of x-rays. When the *Washington Post* devoted a front-page column to medical martyrs, it paused to note the *likely future* martyrdom of Pierre Curie (trampled to death by horses before injuries from radium could worsen) before noting Dally's case ("seven years a martyr to dermatitis," and worse ailments that the *Post* omitted) and that of several more recent ray victims in medical practice.[144] When medical roentgenology pioneer Mirhan Kassabian contracted skin cancer the following July, neither the *Post* nor the *Trenton Evening Times* waited for him to die before proclaiming him an x-ray martyr on their front pages—the latter paper noting that Kassabian had recently come to Trenton in order to testify as an expert witness in a lawsuit in defense of doctors accused of causing x-ray burns in another patient.[145]

Through that note and hundreds of others like it, the word was out that rays could burn, maim, or kill. Though the radiology profession collectively bore extraordinary losses with stoicism and black humor rather than any desire for acknowledgment, the gruesome nature of their declines and deaths and the ostensibly self-abnegating cause of it all made them sympathetic figures. Rebecca Herzig has cannily noted the difference between the hagiographic coverage of the deaths of a hundred or so x-ray martyrs (a term loosely adopted by injured radiologists for themselves, in addition to being the way that newspapers referred to them) and the lack of commentary aroused by a 1929 fire at an x-ray film storage facility that killed 124 people.[146] The same month, a syndicated item updated the list of scientific martyrs, "unsung heroes [who] work with deadly germs, powerful poisons and rays," to include Edwin Ward (dead of radium poisoning) and W. J. Dodd (dead of "severe burns" incurred while improving the x-ray machine).[147]

If this sort of publicity of the physical dangers of irradiation was often melodramatic ("Armless, undismayed, he continued his research until the end") it nevertheless reinforced the close identification of radioactivity and especially x-rays with scientists and physicians.[148] One is not a martyr without a cause, and their obituaries never failed to make explicit that their deaths were not accidents but sacrifices. George Stover, an early radiologist who lost his hands before losing his life to overexposure, was alleged in his eulogies to have said that "a few dead or crippled scientists do not weigh much against a useful fact."[149] It may even be an accurate quote, or at least reflective of his feelings in the last agonies of his illness, but there is no way to know. No craven, regretful, or incurious martyrs were ever depicted in the press, and exposure was never presented as accidental or inadvertent, but simply the consequence of doctors' commitment.

Notwithstanding the martyr stories, though, journalists writing about the novel energies became markedly less sensationalistic after the "radiomania" decade. To a large extent, this was the result of the professionalization of science journalism that came about during the 1920s, with the founding of the National Association of Science Writers and the establishment of the Science Service, a wire service aimed at improving the quality of newspaper science. Radiant energy was deeply bound up with this new science journalism. Press accounts of radiation and radioactivity provided the bulk of that attention, and served as a reservoir of information. Catherine Covert's image of science popularization in early twentieth-century newspapers as an "upwardly tilted spiral" is especially valuable in understanding the role that journalists played over and above simply conveying (or manufacturing) news about the rays. In the model Covert describes, basic explanatory accounts alternated with more sophisticated treatments, allowing readers new to a subject a chance to acclimate while flattering the knowledge of those who had already done so. Each successive "easy" iteration of a story on a phenomenon assumes less knowledge, until eventually the concept was familiar enough to enough readers as to require no introduction at all.[150] Covert developed this understanding while studying the representation of Freudian ideas in American newspapers, a subject that enjoyed an intense but relatively brief vogue in the science columns. By contrast, radiation and radioactivity were constantly in the news for 50 years, and, except during wartime, the number of mentions given to those energies tended to increase year by year.[151] (See Figure 3.3.)

The effect of constant introduction and reintroduction of information about the novel energies, especially during the first two decades (during which scientific consensus about those energies and their properties was slowly cohering) was to provide a solid, basic, broad factual foundation from which individuals could build further, more idiosyncratic understandings. Given the omnipresence of those stories, we can assume that a certain baseline understanding and awareness permeated even to most nonreaders, or casual readers of the papers. Especially in those first two decades, before the establishment of the Science Service and other organizations committed to improving and expanding science content in the media, publishers sought out and promoted ray-stories out of more purely mercenary motives: stories about x-ray ghosts and veins of radium ore under Connecticut captured attention and readership in ways that no other contemporary scientific phenomenon could. But the relationship was clearly a deeply reciprocal one: even as it sold magazines, ray-rhetoric remained as close to the top of the public consciousness as it did by virtue of that constant repetition.

A more restrained journalistic approach to radiant energy did not put an end to enthusiastic flogging of potential medical breakthroughs

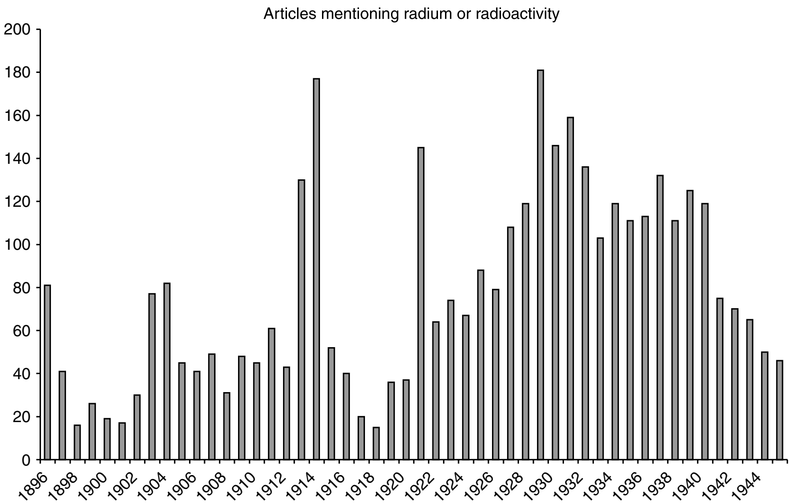

Figure 3.3 Newspaper articles about radiation and radioactivity, 1896–July 1945.

or visions of radium-powered cities, but it did mean that the press' treatment of the rays was more *cautiously* optimistic, and in medical articles, far more likely to include information about the dangers they posed to living things. In 1921, long before radiation was widely regarded as a subtle and insidious environmental hazard in the way it came to be in the postwar period, Edwin Slosson of the Science Service coauthored a long article exploring the dangers that stray x-radiation posed to anyone who shared a building with a radiologist. "But is it the operators alone who may receive harm from these radiations? Alas, no! Among the x rays there are very penetrating ones at the other end of the spectrum for which the walls and floors of our laboratories and offices are but feeble obstructions and our neighbors whether patients or simply house occupants become our unsuspecting victims."[152] This sort of tone, neither alarmist nor triumphalist, sat well with an American public that was gradually becoming accustomed to a newly irradiated world. Acknowledgements of the dangers of irradiation were softened by a comforting inbuilt teleology: yes, x-rays burned, a typical magazine article admitted, but the invention of new "burnless" x-rays by a New York roentgenologist meant that this was already an obsolete worry.[153] True, a *Youth's Companion* article celebrating the "glorious work of the [x-ray] operators" conceded, it was now known that x-rays were often more dangerous than the minor illnesses they were used to treat, but after almost 30 years of refinement, "the danger of X-ray treatment for almost any disease is now no greater than that which we associate with any powerful remedy or agency in medicine, as for example arsenic, quinine, or mercury."[154] Radiation might no longer serve as *miraculous* medicine, but if its considerable drawbacks could be offset by still greater rewards, it could still be a modern *heroic* medicine.

Conclusions

The 1910s and 1920s saw the vulgarization of radiation. In the excitement of their unveiling, x-rays and radium had become emblems of scientific modernity. Now, by virtue of their commodification, they had also become something like lifestyle accessories. The all-enhancing power of the ray lent commercial appeal to everything from books to fertilizer, and every successive product on the market that traded on that appeal reinforced some or all of the central elements of the radiant iconography: vitality, rarity, modernity, weirdness, and above all potency. For all the fantastic breadth of reactions that the rays had provoked during the crazes—everything from unabashed optimism to existential horror—they had existed in an experiential monoculture, in which the laity received their impressions from a very limited set of sources. More variety in the avenues through which these energies could be explored, physically and rhetorically, meant that the connotative white noise of that initial excitement was slowly being filtered into a number of identifiable pitches (though still a fairly discordant sound overall). Advertisements, poems, pulp fiction, and a thousand faintly radioactive tchotchkes each forced an implicit comparison between the way the energies were being represented and the expectations and experiences of the individual. Collectively they formed a crucible in which spurious ideas and images were burned away from nuclear culture, while the more enduring ones were tempered and, over time, subtly reworked.

The significance of this collective reckoning should not be underestimated. On other subjects, the ever-clearer line between scientist and nonscientist in the early decades of the twentieth century had sharply curtailed the laity's willingness to weigh in on scientific topics, except occasionally in the reactionary fashion of antievolutionists. With respect to radium and x-rays, though, the general public maintained a genuine sense of ownership, and took an active role in deciding what the rays meant for them.

To be sure, this sense of ownership was reinforced by the literal investment that American consumers had made in these energies.

The effect here was hardly ambiguous: the net effect of two decades of advertising praising the virtues of radium tonics and shoes fitted scientifically with x-rays could hardly have failed to create at least a presumption that these energies were beneficial, or at the very least innocuous. Lest the point be missed, many purportedly radioactive products included an assertion of their utter harmlessness somewhere on the label, amidst other suggestions of its benign and helpful nature. Especially with respect to radioactive devices presented as illness preventatives, like the emanators, it was not necessary for a user to perceive a real difference in order for them to feel fortified by it, but many users apparently did. And whether that good feeling came about by virtue of a placebo effect, or the salutary effect of drinking enough water (which is how the AMA explained away any reported benefits), or any other mechanism, it reinforced the beliefs that led consumers to buy radium nostrums in the first place. They were tangible assurances that the wonders of science, or the raw powers of nature—depending on how they were advertised—were finally within reach, even if only in a preliminary or attenuated form.

* * *

In the decades following the initial crazes for x-rays and radium, the energies stayed well within public view. It was not necessary to set foot in a hospital or the science section of a bookstore, or even to visit a newsstand, to be inundated with information of one sort or another about radiation and radioactivity. This information was part of the fabric of day-to-day life of Americans in the early twentieth century in spite of the energies' limited immediate relevance to most nonscientists. Invitations implicit and explicit to experience the new energies, or to discuss them, or to speculate about them, or to learn about them, or simply to purchase them were ubiquitous. That very ubiquity also contributed to the enduring sense of novelty and fascination: while some arguably more significant and transformative technologies captured the public's attention for a period and then became an unremarkable feature of the landscape, x-rays and radioactivity were actively being reimagined and represented, and sometimes literally repackaged, by an ad hoc and diverse set of actors ranging from poets to pitchmen.

More than we are necessarily comfortable admitting, our knowledge of the world around us is informed by those who would sell us something, a circumstance that has prevailed in American culture since before the discovery of x-rays and radioactivity, but which found florid expression through them. The laity saw potential of all sorts in the Roentgen rays and gamma rays—potential to heal, potential to burn, potential to drive a steamship, potential to blow it up—and catering to those expectations was a vast and lucrative enterprise, even excluding explicitly medical endeavors. Speakers received honoraria, and drummed up business for their clinic or studio in the process; writers sold stories, dancers lured in audiences. Beauty shops and shoe stores turned a profit by creating a need where none had existed before, and rendered themselves "scientific" in the process.

Even as it made them more accessible to a lay audience, the commercialization of the energies sharply reinforced their association with the scientific establishment. Lecturers and demonstrators were free with their invocation of magic and alchemy to illustrate the properties of the rays, but they did so on stages littered with laboratory apparatuses, and were preceded by their own scientific bona fides, and as the example of Hammer, Edison, and especially Marie Curie shows, the more prominent the scientist, the more attention their comments on radiation and radioactivity received. If the magic words that bespoke connection with nuclear emanations were not the first terms of science's art to be widely employed to commercial ends as brand names or advertising keywords—they were preceded at least by the cluster of terms associated with sanitation in the late 1800s—then they were at least without parallel in the extent and breadth of their use in their first half century.

Commercial deployments of ray-talk also served to refresh and sustain the connotative associations that grew up around the terms. "X-Ray" in the brand name of a product forced consumers, however subconsciously, to revisit their understanding of how that term could be applied in order to understand the reason behind the name. Likewise, a product claiming to contain radium challenged those who saw it advertised to reconcile the claims made for the item with their knowledge of radium's properties. Products and their advertisements kept the jargon of radiation constantly in the public eye. (Literally so, in the case of Degnen's Radioactive Lenses, spectacles painted with a radium compound.) Americans did not buy these products because they were simply helpless before the stratagems of manufacturers who cloaked their products in the guise of the new energies, and advertisers who tied the new energies ever more tightly to infallible Science. Rather, they bought them because the claims seemed so plausible in light of the more extravagant claims that had been made in all seriousness by unimpeachably orthodox members of the scientific and medical establishments.

In the era of the crazes, both fears and fancies had been born of ignorance on the part of the nonscientific public. Of all the information that flashed around the public sphere at the turn of the century, little of it was reliable enough to refute the assertion of the moment that x-rays could read thoughts, or that radium bombs would be the fuse that set the world on fire. The growing number of participants in the nuclear culture of the subsequent two decades, though, were better informed on both points by virtue of the colonization of the subject by commercial interests of various kinds. As a result, reactions that had been based in fascination gradually became reactions to the familiar: the energies of the x-ray machine or the radium capsule were still *mysterious*, in that their effects and potentials were still obscure, but they had lost some of the *mystique* that came with being the rarefied creatures of a few pathbreaking scientists or early-adopting physicians.

The candor about the rays' harmful effects on living tissues demonstrated by print popularizers did not entirely fail to register, but it was heavily offset by the many sources of good news with respect to such applications. From the perspective of a population increasingly impatient with promised panaceas, it was not particularly important that some of that news took the form of a sober report on the findings presented at a radiology conference, and some came from the labels pasted on the sides of ceramic jugs: illusory progress nevertheless felt like progress.

* * *

As commercial actors took a greater role in defining the terms of the nuclear discourse, scientists receded from the discussion. So quickly had the works of Becquerel, Roentgen, and dozens of their immediate contemporary colleagues in the physical sciences shifted the direction of inquiry in their fields that there was only a brief window of time in which a scientist could gain any particular notoriety for working with x-rays or radioactivity. Not every shifting paradigm attracts much attention outside of the community it most directly affects, but as it happened, in this case that notoriety translated into actual fame beyond the boundaries of the scientific establishment. In 1903, physicists or chemists working on radioactivity (and therefore in possession of some refined radium) were in rare company and, by virtue of the extraordinary nature of the phenomena they studied, necessarily raising more questions than they answered. A quarter of a century later, there was no novelty or transgression whatsoever in working on the subdisciplines spawned by those questions: atomic structure and the quantum hypothesis were thoroughly mainstreamed. This meant that there was little special advantage to be gained by engaging directly with the public: where William Hammer and Frederic Soddy had advanced their financial and professional prospects enhanced by writing books and giving lectures, later researchers could not. In any event, the era of the scientist-popularizer was passing at this time, and the responsibility was increasingly being passed to commercial popularizers and journalists.[155] This did not in and of itself affect the overall intensity of the nuclear culture of the age; there was, to put it mildly, enough interest in the subject without moonlighting scientists fanning the flames. That concession did, however, eventually have the effect of making the topics that nonscientist popularizers took as their subjects somewhat idiosyncratic: William Laurence, the *New York Times* science reporter who went on to cover the Hiroshima bombing, recalled an editor killing a story by saying, "the publisher doesn't like cosmic rays, and neither do I. Furthermore, let me tell you, I don't believe in atoms and have but slight faith in molecules."[156]

By the close of the 1920s, scientists working with the new energies were largely content to let such matters lie, submitting to the occasional indignity of a newspaper interview but otherwise leaving the laity to its own devices. That physicians took exactly the opposite approach to their colleagues in the physical sciences with respect to the public understanding of radiation figures heavily in what happened next.

Chapter 4

Backlash

By the end of the 1920s, the wholesale commodification of x-rays and radium had made them ubiquitous. Nonscientist Americans could and did interact with them physically, intellectually, and rhetorically. Some were indifferent, and many had retained through those first few decades the vague dread or acute fear that had been part of the spectrum of reactions from the start. Those misgivings might be the result of specific fears having to do with the direct experience of irradiation itself. They might also be due to a wounded sense of Victorian propriety, a reaction against a new physics that seemed daily more metaphysical, or a manifestation of the broader antimodern sentiment that had not only Soddy in its sights but also Joyce, Stravinsky, and Picasso. For the most part, though, science and medicine were held in high regard, and by virtue of decades of popular science writing, x-rays and radioactivity were more than ever the emblems of those disciplines.

Two forces corroded that broad popularity in the 1930s and early 1940s. The first was a chronic complaint, the persistent effect of decades of promises and expectations that had gone unmet. Thirty-five years of roentgenology had failed to cure cancer outright, and offered individuals far less hope than was hoped for. X-rays had fulfilled still more poorly the expectations that they might be windows into the soul, or the spiritual realm, or even the next room. They had, however, gotten steadily better at making useful diagnostic images, and the machines that generated them had become less ostentatious, less terrifying, and less prone to injure the patient. Radium, for which an even wider range of applications had been imagined, had succeeded unambiguously in only one of them: it could be made into a reliable and permanent light source, just bright enough to indicate the location of the electrical light switch in a dark room. It was not a panacea, or at least it was not universally regarded as such. It had not been converted into a ready source of heat or electricity. And it remained so exasperatingly rare, at least in its refined form, that even those who believed it capable of tricks like making crops grow held no hope that it could ever really be usefully applied.

The second factor that sapped the public enthusiasm for x-rays and radioactivity was more acute: between 1925 and 1934, a series of deaths and illnesses directly attributable to irradiation injected a persistent and troubling note into the discourse about x-rays and (especially) radioactivity. The danger that x-rays posed to physicians and experimenters had been generally known since the turn of the century. The change in perception of radiation's dangers came about not from a different kind of science reportage, but from a different kind of victim: industrial workers and patent medicine consumers who, unlike radiologists, never intended to be martyrs and could take no solace in the notion that they had sacrificed themselves for the greater good.

The Bad News Intensifies

The occasional commentary on disfigured or dying radiologists had continued apace through the 1920s. This was not the result of any special attention given to it by reporters; it was simply the grim actuarial reality of the severely foreshortened life expectancies of physicians working with x-rays in era before protection was effective or widely used. However pious and foreboding these eulogies were in the instant, they never reached any sort of critical mass in the print media until 1925, when New Jerseyans learned of the illness of certain employees at a factory that used luminescent paint. Thousands of articles would follow on the suffering, decline, and inevitable deaths of employees of the United States Radium Corporation. Dozens of them had ingested dangerous doses of radium when using their lips to bring to a point the extremely fine camel-hair brushes that they dipped in radium-impregnated luminescent paint. The "radium girls," as they became known, have become fixtures in American labor history.[1] The dial painters were able to transform their constant presence in the newspapers into sufficient agency to change the policies of the powerful company that had employed them, and then to force public attention to occupational hazards in ways that were felt far outside of the Orange, New Jersey environs in which they had been poisoned. Yet their decline, dolorously drawn out for years on the pages of one newspaper or magazine after another, also colored the way that radioactivity was depicted for public consumption. For more than a decade after the first report, and with shocking frequency during the first few years, news of radium was principally news of its role in the slow physical destruction of these women. The protracted legal fight the dial painters engaged in with their former employer made them immensely sympathetic, but while US Radium was portrayed as the real villain in most such accounts, the element radium was abruptly recast as an unambiguously dangerous poison, with references to its medical applications scant and heavily qualified.

What might have been a local matter, had it involved a mere chemical poisoning, became a protracted spectacle by virtue of the fact that it involved the miracle cure of the previous decades. There was a surge in national publicity in 1927 when some of the exposed workers filed suit against US Radium in a New Jersey court, which formalized and legitimized their complaint, and provided the established narrative structure of trial coverage.[2] Marie Curie weighed in, lending moral support and her personal spotlight to the workers' cause, although no more optimistic prognosis than the notices of incipient death that the newspapers were printing. The workers—those who were party to the suit as well as other radium workers, some of whom had not fallen ill—became the targets of a press corps in pursuit of the rich emotional drama inherent in a story of doomed innocents, and many cooperated with interviewers. As the roster of victims grew larger, thanks in part to the attention given the lawsuit against US Radium, so did the number of subjects for profile pieces grew. Other radium-using manufactories, like the one in Ottawa, Illinois, were also drawn into the legal arena. Inevitably, though, interviews and legal process stories were replaced with obituary notices, which came in a steady drip over the course of decades and which represent a sizable portion of media attention given to the subject. The public relations battle was joined in earnest by the radium paint industry: the Ottawa plant, for example, ran a full-page statement in the local newspaper at the height of the New Jersey legal battle, arguing that the so-called radium poisoning was in fact mesothorium poisoning (that is, ^{228}Ra, a more radioactive isotope of radium than the most common one, ^{226}Ra), and mesothorium was an "impurity" that they had never suffered in their own paints.[3] This was a clever way of rehabilitating radium while impugning a competitor. Nevertheless, the tide of the newspapers was generally against them.

The painters' death notices, recreated in any number of ways by individual newspapers, contained certain recurring themes that painted a strikingly malevolent portrait of radium—a substance that had been, in those same newspapers, recently portrayed as a cure-all.

There was usually a running tally—Margaret Carlough was the third victim, Irene La Porte was the twentieth, Catherine Schaub was the second of the original five, and so forth. Often, those notices were run as news items, rather than included among the obituaries. Into the 1930s, the accounts tended to stress the latency of the poisoning: Mildred Cardow's radium poisoning lasted four years, Pauline Kenton's lasted nine years, Grace Fryer had been "doomed to death almost ten years ago." The lengths of their illnesses were always expressed in terms of the duration of suffering, starting with the moment of the initial diagnosis, not the onset of serious illness. The mental anguish at the inevitability of their death, and the knowledge of the suffering that awaited them, were also part of the calculus with radium poisoning, and the media attention reflected that.

Some deaths attracted more attention than others. Quinta MacDonald, as the first of the original five plaintiffs to die, was one; her autopsy was above-the-fold news and served as confirmation, if any were needed, that the workers' plight was a real one. Harrison Martland, the Essex County medical examiner who would spend much of his career examining the US Radium workers and other apparent radium victims, declared that her body bore out his theory of radium carcinogenicity.[4] He had said as much the previous year about bone marrow necrosis when Sabin von Sochocky, formulator of the paint mixture used by the plant, had succumbed to aplastic anemia. Newspapers, already in 1928 decidedly antipathetic toward the US Radium Corporation for its legal tactic of delaying the dial painters' lawsuit, underlined the irony of von Sochocky's death and reiterated his repeated denials that his illness was the result of radium exposure.[5] The contrast in tone between the obituaries for the workers, invariably presented as simple and virtuous victims, and of Sochocky—perhaps the first radium researcher denied "martyr" status in death—created a moral dimension for the action of radium, a substance that was already virtually personified. Martland himself had been grateful for Sochocky's assistance in researching radium's effects on his workers, and spoke well of him after his passing, but sympathy was lacking elsewhere for the man associated with what the *New York World* had called "one of the most damnable travesties of justice that has ever come to our attention."[6]

A more morally ambiguous case than either Sochocky or any of the media-anointed martyrs that had preceded him came in 1932 with the very public death of steel magnate Eben Byers from radium-induced illness. Byers began drinking "Radithor," a radium-based patent medicine sold by the semi-legitimate entrepreneur and unimpeachably earnest radium advocate William Bailey, in 1930 on the advice of his physician, to soothe a back injury and as a general health aid.[7] (See Figure 4.1.) Radithor was, unfortunately for Byers, a real rarity among purportedly radioactive tonics in that it actually contained radium. Bailey advertised Radithor nationwide, and thousands of customers must have consumed some, but because its active ingredient had an actual cost, the price (about $1.25 per two-ounce bottle) was such that few could afford to drink the thousands of bottles that Byers did over the course of the next several years. Because of this voluntary, and, it was occasionally suggested, immoderate consumption, enough radium displaced calcium in Byers's bones to effectively irradiate him from the inside. This caused bone and tissue necrosis, anemia, leukemia, and, after a number of futile surgeries and a prolonged and horrifying wasting, death.

The manner in which Byers died, via voluntary and knowing consumption of radium, was so rare as to be practically unknown before or since. A close friend, Mary Hill, with whom he reportedly shared his supply, preceded him in death, and an insurance company executive who died in 1937 was also suspected of having consumed a great

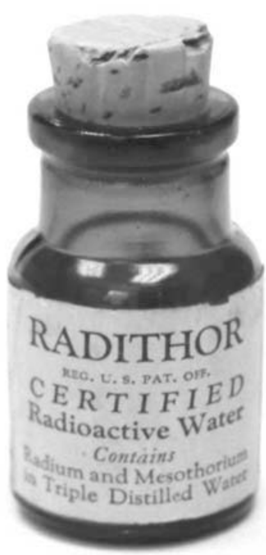

Figure 4.1 Radithor tonic. Radithor, one of the relatively few "radium" patent medicines to actually contain significant amounts of radioactive substances. Photo courtesy of Paul Frame, Oak Ridge Associated Universities.

deal of Radithor. Federal Trade Commission investigations identified several Radithor consumers suffering from necrosis of the jaw, but those are the only certain cases in the period.[8] But Byers had testified before a FTC panel that charged Bailey with misrepresenting his radium preparations (calling them "harmless"), and the publicity surrounding his death provided the impetus for immediate efforts to ban radium tonics. The FTC, the American Medical Association, the New York City Commissioner of Health, Harrison Martland of the dial painters' investigations, and various other regional health authorities all joined in support of the radium ban. The subsequent barrage of stories on the investigations, hearings, and forums occasioned by Byers's death, including articles published at every stage of the lengthy autopsy and postmortem analysis, was characterized by unremittingly negative coverage of consumer radium products. This state of affairs persisted until the trade in radioactive tonics was essentially dead.

That sustained attention to the radium tonic industry turned up some interesting results. New York City mayor Jimmy Walker was reported (accurately) by alarmed friends as having used a radium emanator for six months at the time of Byers's death. The *Times* paused for a paragraph to make the distinction between emanator water and tonic water, but offered no assurances for the Mayor's continued good health. For his part, Walker claimed he had felt no effect on his rheumatism in any event, and sounded disinclined to continue its use.[9] For all the condemnatory rhetoric, Radithor got a spirited defense from a number of people within Byers's circle. Bailey himself was one of them, pointing out that he himself consumed Radithor and had suffered no ill effects. There can be no doubt about his sincerity on this point: Bailey's body was exhumed in 1969, two decades after his death, and was found to be highly radioactive.[10]

Bailey's further defense that he offered Radithor only by prescription does not seem to have been true in general, but it was in Byers's case, thrusting his doctor and several others publicly named by the FTC into the spotlight. C. C. Moyar, Byers's physician, also claimed to have taken more Radithor than Byers ever did, and blamed Byers's death on blood diseases that led to gout.[11] Moyar appears in several press accounts, and is each time quoted in such a way as to suggest defensiveness and a guilty conscience; this may have been a fair assessment, but his hostile mood toward the press was probably also influenced by the fact that they were also circulating the claim of a New York physician that he had one hundred patients suffering from radium poisoning. That was almost certainly false: Bailey had not produced Radithor for two years in 1932 (owing, he claimed, to the Depression). Moyar claimed only to have had a dozen patients on it at one time, and would have had to have sold implausibly large quantities of the tonic to sicken so many patients. But the fact that a mini-epidemic of radium-poisoning victims seemed so plausible is itself an insight into the sudden shift in the collective wisdom regarding the substance.

The change was a permanent one. Byers had enjoyed a certain degree of notoriety during his life, but his death was a scandal. Radithor became a sort of informal benchmark of danger. F. J. Schlink, founder of the Consumer Research Institute, used it as an upper bound for the threat presented by emanators: they were bad for the health, but not *Radithor* bad.[12] So many people were talking about it, in fact, that Arkansas senator Royal Copeland felt obliged to defend the safety and healthfulness of his home state's Hot Springs from the floor of the Senate. They were, he conceded, indeed radioactive (and advertised by the government as such) but from radon gas. "Because of the confusion of mind on the part of the public, there has been an unfortunate reaction against all radioactive waters. That is a public sentiment which I sincerely regret," he said, proceeding to quote at length from *Time*, the *New York Times* (NYT), a circular from the French Chamber of Commerce, and other barometers of public discourse that reflected uncertainty about the difference between radium and radon, and fear that thermal springs would do to them what had been done to Byers. Copeland's further eloquent defense of Hot Springs as a miracle of nature, medicine, science, democracy, and folk wisdom was probably necessary, but ultimately unequal to the task of rehabilitating radioactivity, even within the eyes of his own government.[13] Seeking to drum up support for legislation that would grant them greater jurisdiction over radioactive substances, the FDA summarized it this way in a radio broadcast: "When Eben M. Byers lost his health, he was persuaded to dose himself with 'Radithor certified radium water.' Like many ill people, he was willing to try anything that offered a cure. Perhaps he reasoned that if Radithor didn't cure him, at least it wouldn't do him any harm. But the medicine killed him. It literally disintegrated the bones of his head."[14]

In the newspaper accounts of Byers's decline and death, there were a few other such hints that he bore some of the responsibility himself. His consumption of the tonics could be read as immoderate, if not rash. By contrast, Marie Curie's exposure to radiation (both in the form of radioactive substances, and the battlefield x-ray machines she helped operate) was never presented as reckless. Perhaps because of the reverence that she was accorded by American audiences, the news of her death in July 1934 did not include gruesome details of her decline and suffering. Curie had been enormously popular in the United States, especially following two ceremonial visits, in 1921 and 1929, where she had been presented with gifts of radium. Sixty-six at the time of her death, she had been frail for years, and occasionally hints surfaced in the public discourse that this was the result of her various exposures to radiation. While she lived, she was inevitably described as a shy, sober, matronly woman unusual only for her keen scientific acumen. The tragic death of her husband, her shabby treatment by the French scientific establishment, and her much-celebrated labors in reducing tons of pitchblende into tiny crystals of radium compound made complete the image of the tortured scientist struggling for the benefit of a humanity that could scarcely understand her work: one of her obituaries summarized it as "endless but intelligent drudgery."[15]

When her death was announced, this romantic portrait was once again set forth in the obituary literature, but with a palpably venomous regard for the radium exposure that was universally suspected as the cause. In life, Curie had been more reluctant than many of her peers to firmly ascribe to cumulative irradiation the various ailments that researchers, including herself, had suffered. She had lent moral support to dial painters' cause, but contrasted their exposure with what she or other laboratory workers might acquire. In the tradition of the charter generation of radiologists, she adopted a sort of protective agnosticism, while encouraging others to exercise greater caution than she herself had shown.[16] In any event, she firmly rejected the idea that she was suffering from her work on radium, and the martyr label that went with it, while she lived. This was not only a matter of her celebrated modesty, but a protection of the bulk of her life's work: for the 15 years preceding her death, one of the principal missions of her Radium Institute had been the furtherance of medical applications for radioactivity. Her eulogizers flatly contradicted her, presenting an account of her end in which radium was a vaguely malevolent force at best, the guilty party in what amounted to a negligent homicide, with only a few oblique references to its beneficial applications in medicine.

The headlines alone convey the thesis of the death notices: she was a "Victim of Her Work on Radium," a "Martyr to Science" whose death was "Hastened . . . by the Effects of Accumulated Radiations." The Science Service wire organization wrote a supplementary article specifically aimed at clarifying that point: "While a lung infection is reported responsible…her thirty years of research with radium and its penetrating gamma radiation is held to be the basic cause of her death." Science Service had been founded to combat sensationalism in the science press; it frequently accomplished this by adopting an almost fawning reverence toward the scientists it covered, setting forth their pronouncements as holy writ. While she lived, Curie had benefited from that heroic portrayal of her intellect and perspicacity as much as any other scientist. A day after her death, their reporter described a 30-year campaign of futilely attempting to treat the symptoms of her illness before "finally, she succumbed to the ignorance of the danger she was facing."[17]

Commercial Irradiation Goes Undercover

When Curie died in 1934, American nuclear culture was in its fourth decade of riotously diverse perspectives on irradiation, particularly when it came to the perceived healthfulness or harmfulness of x-rays and radium rays. The last of those decades, marked by the beginning of the dial painters' saga, had seen enough especially bad news to make awareness of the potential dangers that radiation posed nearly universal.

It did *not*, however, bring about wholesale fear and loathing, or even make most Americans particularly squeamish about undergoing irradiation themselves. Rather, it tended to reinforce the notion that some sort of mediating agency was necessary to insure the safety of being exposed to radiation. This argument was earnestly advanced by orthodox medical professionals, who hoped to recharacterize ionizing radiation as the energetic equivalent of other heroic medicines, where the steady hand of the expert was necessary to find the narrow window of healthfulness between a poisonous overdose and a useless underdose. In practice, though, the general public demonstrated ample willingness to trust other sorts of agents besides medical specialists: shoe salesmen, beauticians, and the class of entrepreneur the AMA preferred to call "x-ray quacks" were sufficient guarantors of the safety of irradiation for much of the laity.

The history of the shoe-fitting fluoroscope has been exhaustively considered by Jacalyn Duffin and Charles Hayter, who trace its roughly 30-year heyday in the consumer landscape, from the mid-1920s to the mid-1950s, and conclude that savvy and manipulative salesmen, the pressure of living up to an ideal of "scientific motherhood," and the inherent fascination of children with the spectacle of seeing one's feet (or fingers, or nearby cats) under a fluoroscope were responsible for the popularity of the device even though all adult parties involved probably should have been more sensitive to the dangers involved. Given the contemporary example of the radium dial painters, the martyrs to radiology, and (latterly) the victims of Hiroshima and Nagasaki, Duffin and Hayter argue that the use of unmaintained, unregulated x-ray machines by untrained salespeople on children "seems to be a triumph of capitalism over common sense."[18] The surreal attraction of seeing one's bones in a fluoroscope screen is obvious enough, even if salesmen knew and "scientific" mothers surely occasionally suspected that the machines were of greater value as sales goads than shoe-fitters. Nevertheless, the apparent carelessness with which parents and children regarded the fairly intense irradiation of the shoe-fitting machines can be explained with reference to a number of discontinuities between that experience and what they might have heard about radiation.

The typical shoe store machines, for instance, were built to look imposing and significant, and took the form of large, immobile wooden cabinets that encased—and therefore concealed—the entire ray-generating apparatus itself. The only instrumentation visible from the outside was a panel of three toggle buttons to control the intensity (one each for men, women, and children), a power switch, and occasionally an unmarked meter. In clear contrast to most clinical apparatuses, the machines were figurative black boxes that took the form of literal wooden boxes, with the offending technology out of sight and nothing else in view, like warnings or even visible electric cords, to bring it back to mind. Moreover, fluoroscopy did not necessarily call to mind x-raying, since patients rarely if ever saw what the doctor did during fluoroscoping in the way that they could view film or glass exposures after the fact.

Given the intensity of the rays in such machines, and the relatively brief duration of their intended use, they were also unlikely to actually produce any physical effect. Certainly, they could not produce any irritation that would be immediately associated with the shoe store visit: no matter how "scientific" the shoe-fit, mothers would never have stood for injury to their children.

But another x-ray machine in common commercial use was aimed specifically at producing a bodily reaction. Hair loss was one of the first observed physiological effects of the x-rays, along with skin irritation and ulceration. After the use of nuclear weapons in Japan, which gave the world its first look at widespread radiation sickness, this hair loss would come to be understood as the herald of a grim and likely irremediable decline—the sign of a body taxed beyond its ability to cope. The early x-ray researchers, however, had treated it simply as a point of reference. One of the earliest standards of radiation dosimetry was the "epilation dose," the amount of radiant energy sufficient to cause hair to fall out. That casual attitude toward the symptom, and the x-ray's extraordinary reliability in producing it (given sufficient dosage) meant that even as word was slowly reaching the public of the grisly ends met by radiology pioneers, beauty salons were awakening to the potential commercial appeal of a reliable, painless, and long-lasting depilatory treatment. By 1925, women could have unwanted hair removed in a manner guaranteed to be "scientific—safe—sure," the watchwords of the Tricho hair removal system that had established franchises in at least 51 different US cities.[19]

By 1922, the Victor X-Ray Company was also offering a line of x-ray generators suitable for beauty shop use.[20] The model had been designed for use by physicians, but Victor's sales agents cheerfully recommended them to beauticians. The initial cost of $385 was considerable, but the financial logic from the perspective of the franchisee was compelling: the treatments might fetch $10 or more apiece. Considering the ease and effectiveness of the treatment, ignoring any long-term health complications, that price made sense for customers, too.

Tricho made a point in its early promotional literature of the professionally supervised training that its beautician-franchisees had undergone. There was, in fact, an optional two-week course that franchisees could take advantage of, though presumably most did not.[21] Lest any potential customers fear unintended consequences of irradiation, though, Tricho shops were armed with literature ready to invert—or at least dispel—those suspicions. The rays were "void of any sensation whatever," and did not scar, pamphlets promised.[22] They also built a moral case for the use of the most modern, scientific means possible: "all normal women desire to be beautiful," one of its magazine advertorials read, and "impelled by this desire, great numbers of women have resorted to futile, dangerous and injurious means of removing disfiguring superfluous hair." It was this sorry state of affairs, according to the Tricho narrative, that had moved medical doctor and hospital radiologist Albert Geyser to develop a system that "dries up hair roots in a manner similar to that of gradually getting bald, instead of attempting their *sudden and violent destruction*."[23] Its advertisements carefully extended the professional aura of the medical radiologist into the beauty shop, by conflating the two with repeated assurances that the "operators [were] trained under personal supervision" of Geyser himself, and by noting that its machines were "endorsed by physicians and beauty experts" alike. Physicians, after all, could vouch for the safety of the rays—according to the ads, by their willingness to let their "wives, daughters, and sisters" use them—but their cosmetic effect needed the approbation of a specialist.[24]

Unknown thousands of women received beauty parlor x-rays; some, of course, eventually suffered serious complications as a result. Rebecca Herzig's study of these "North American Hiroshima maidens" (the term is a recent coinage) considers why, in the 1930s and 1940s, when any sort of x-irradiation was widely believed to be deadly at worst and of highly debatable virtue at best, so many women defiantly embraced this "controversial" technology. Herzig concludes, plausibly enough, that the epilators' tight rhetorical embrace of science in all its progressive glory was enough to overwhelm any reticence that customers may have had about the risks of exposure. Indeed, the AMA's stern warning that radiation was only fit for the most serious problems may have implicitly encouraged some women to seek out x-ray epilation. Whether clinically hypertrichosis or not, unwanted hair presented real social and psychological stresses to many women, especially those who were already somewhat marginalized by their ethnicity or economic status.[25]

There is another explanation, though: the simple but telling fact that, past a certain point, references to x-rays are simply not to be found in the advertising literature produced by Tricho and its competitors. In 1923, Geyser freely embraced the term "Roentgen ray" in an adulatory business column.[26] By 1928, however, the Roentgen ray had been recharacterized in Tricho promotional literature as a "vibratory wave," the process was called the "electric wave method," and Geyser was no longer characterized as a radiologist but as a "lecturer on Medical Electricity."[27] The *safety* of Tricho rays was much discussed in its promotional materials: the AMA noted that Geyser trumpeted a New York City Board of Health certification that his machine was in good working order as evidence that it had been proclaimed "SAFE," but at every turn in the 1930s and onward, x-rays were only invoked in contradistinction to the light emitted by beauty parlor machines[28] In one pamphlet, x-rays are described as being "dangerous even in the hands of experts, when used to remove hair. It is mentioned only to be condemned," along with the rays of radium (which is, characteristically, described as being dangerous *and* expensive for purposes of hair removal). The many different wavelengths that the term "x ray" encompassed were set against the single "Tricho wave" that their machines isolated, a "specially selected wavelength" that, like radio waves, was harmless and "cannot be heard, seen or felt."[29]

This deliberate obfuscation of the nature of the epilating rays was pursued seriously and effectively. Investigating a Tricho competitor, the National Better Business Bureau took it upon itself in 1930 to determine whether or not something called the "Rowe method" used x-rays, but got neither confirmation nor denial from the proprietors, who cited trade secrecy.[30] Neither could the AMA, who occasionally fulminated against beauty parlor machines in its publications, but it was in little doubt. In some locales where x-ray operators had to be licensed, Tricho owners registered themselves; in others, they ran afoul of those laws.[31] The Cleveland branch of the BBB reported in 1930 that "a young woman in the Tricho System office who was interviewed was asked if the system involved the use of x-ray and she stated that it positively did not," then hastened to recite a litany of assurances that it was harmless in any event.[32] She may very well have believed that to be the truth. Even when the actual operators were willing or able to inform their customers that the machine in question produced x-rays, the rigid refusal of the machines' distributors to acknowledge that fact speaks to the toxicity that casual x-raying had lately acquired in the public discourse.[33]

For all their longevity on the market, and the relentlessly optimistic tone of their promotion, the market for nonmedical x-rays and consumer radium was overwhelmed by the events of the late 1920s and early 1930s that soured the public (for the most part) on radium as a health tonic. The manufacturers tried to swim against the tide as long as they could. One notable tactic was an abrupt change in the language used to describe the active principle in their product. Whereas in the 1910s and 1920s the emanators were described as *radium*-charged devices that gave off *radium* emanation, the better to ride the coattails of enthusiasm for the element itself, by 1930 they instead billed their products as sources of *radon*. Take, for instance, the Radon-Izer that replaced all other models of radium emanator offered by the Chicago Radium Company starting in 1929. Its literature assured the prospective buyer that it released nothing but healthful *radon*—and explicitly not radium—which it described a gas that stimulated the body to health just like oxygen or ozone did. Another tactic was to try to preserve the connotations of "radio-active" vitality while eschewing the radioactive substances. In terms perfectly pitched to appeal to the core of the drugless healing movement, the bottlers of Ray-X Water concluded their advertisements with the legend "Ray X normalizes . . . Nature cures."[34] And in terms equally welcome to a newly radium-averse public, by the 1930s when Ray-X water was produced, they also took care to note that their product was water *treated by* irradiation, but contained none of the element itself: rather, "Ray-X is 100% Pure distilled water subjected to a very powerful series of RAY treatments."[35] Even Claremore, Oklahoma (of Will Rogers fame), had by 1932 begun inserting the cautionary note "Contains No Radium" onto the advertisements for its "Radium Water Crystals."[36]

Commercial radium vendors also tried, sporadically, to mend fences with their detractors in the media. The owner of the Radium Ore Revigator Company approached the AMA on several occasions between 1926 and 1931 to try to bring his product in line with the AMA's expectations—without sacrificing the radioactivity that made it saleable in the first place. Emanator salesmen wrote to the investigators in the radium dial painters case, begging them to make a distinction in their news appearances between harmful radium and healthful radon. The distributor of a "thoroughly reliable radium emanator" wrote to Harrison Martland in 1931, plaintively asking if it was "fair to compare the radium-dial painters' unfortunate experiences with radium emanations used for the advancement of well-being?"[37] "Don't you think, Doctor," wrote another emanator salesman, "that it is wrong [to] retard the development of possibly the greatest commercially beneficial element in existence?"[38] This was probably a false step: Martland could not possibly have been moved by appeals to emanator salesmen's *commercial* interests, and in any event had no problem painting radium and radon with the same brush. But the plaintiveness apparent in these letters gives some sense of how quickly the collective mood was souring on radium, and woe betide the entrepreneur caught on the wrong side of the zeitgeist. To the legend "Radiumac Does Wonders," the established tonic brand with a suddenly unfortunate name had by 1931 been forced to add "contains no radium" in its brochures.[39]

Medical and State Actors Change the Tone

In the initial decades of American nuclear culture, alternative health practitioners (whether utterly earnest or wholly fraudulent) had had to ask themselves the same basic questions about x-rays and radium that their orthodox competitors had: what is the value of these energies for my patients, my practice, and my profession? Across the divide that separated the naturopath and the allopath, the answer for many had been the same. Irradiation was *probably* a beneficial treatment for certain diseases, and *certainly* a desirable thing to be able to offer patients who needed or expected it. Nuclear medicine was not an exclusively allopathic concern: unorthodox healers operated x-ray clinics, offered various forms of radiotherapy, and bottled radioactive patent medicines.

But while orthodox medicine became, year by year, more comfortable with therapeutic irradiation, the opposite was true of most alternative traditions. The misgivings had begun, in the early days of clinical x-rays, as cautious rumbles from physicians on the periphery of the medical establishment. Osteopath E. R. Booth's 1905 antiestablishment polemic *History of Osteopathy*, reprinted as late as 1924, predicted the same quick end for x-ray and radium treatments as for the other miracle cures that MDs had once embraced. "It has been only a few months since the X-ray and radium were heralded as sure cures for cancer. The present writer said then to a very sick patient that she would live to see those medical fads things of the past, just as scores of others that had been relegated to the therapeutic waste-basket are now known only to history." Booth believed he saw the tide turning already: "Radium, for which so much was claimed only a few months ago as a curative agent, according to recent reports is being abandoned."[40] The following year, the physiotherapist and self-styled drugless healer Otto Juettner, who was otherwise favorably inclined toward scientific medicine, warned that "X-ray therapy, is not on the same plane of scientific exactness" as more naturopathic traditions.[41] By 1910, Albert Abrams—future bête noire of the AMA as the founder of Radionics and another drugless healer, but at the time still an orthodox practitioner—suggested in a decidedly regretful tone that the potential hazards of x-irradiation outweighed what he saw as its meager diagnostic benefits.[42] And by 1919, alternative practitioners had begun to use the rhetoric of "healing light" against x-rays, promoting various forms of visible-light and ultraviolet therapy as not only healthful in their own right but also specifically indicated for the treatment of x-ray and radium burns. T. Howard Plank admonished doctors and patients alike to "remember that actinic rays are constructive, differing therein from X-rays or radium gamma rays, which are destructive of normal as well as of diseased tissue."[43]

As the potential dangers of x-irradiation became more apparent to the public at large, thanks in part to the perennial news coverage of physician "x-ray martyrs," other ray therapies found it possible and even advantageous to tack into the changing wind of sentiment. Some ray-therapists began advertising their own techniques as not merely safer than x-rays, but especially well suited to cure the damage that x-ray (or radium) exposure had caused. The notion that milder rays were "antagonistic" to x-ray burns became a commonplace by the mid-1930s, at least among those who advocated their use.[44] This was the special conceit of the "Spectro-Chrome" device manufactured and marketed by one Dinshah Ghadiali, a flamboyant figure who billed himself as "the Parsee Edison." He had had the distinction, in February 1896, of being the very first public lecturer on the Roentgen rays in New York City, when he had described them in far more positive terms as "a lower physical manifestation of the astral light on the physical plane, and as such has been long known to Eastern oculists." A quarter century later, there was far more money to be made in exploiting fear and hostility toward the rays. The faceplate of the Spectro-Chrome, a metal box containing an incandescent bulb, a projector lens, and a series of colored filters, clearly stated that the device was "NOT for the Emission of Infra-Red, Ultra-Violet, or X-Rays"[45] The advertisements and instructions also made it clear that adjusting the settings of the Spectro-Chrome in a specific way would alleviate damage from x-ray or radium exposure.

Dinshah knew his audience well: he was a huckster, but an effective one. By the time he began marketing Spectro-Chrome therapy, it was apparent that x-irradiation was not a miracle cure for cancer, notwithstanding the decades of claims to the contrary that had often been advanced on behalf of the scientific medicine with which the AMA had become associated. There was an audience of disillusioned or seriously injured patients open to counterclaims from a different sort of healer, and by appealing to the cancer patients that radiotherapy and radium treatments had not cured, whole hospitals (of varying degrees of orthodox legitimacy) were filled. The Baker Hospital of Iowa was preaching to the converted in its 30-page, full-color brochures, when it recited a litany of charges against allopathic doctors and their infernal machines: "If you have a small cancer the size of a match head, they start with X-ray, electric needle or the knife and scatter it worse. Then advocate radium and burn it deeper and scatter it more with dreadful pains resulting. Then they repeat, start cutting again, more X-ray and more radium until your cancer has spread throughout your system and to the glands. They keep repeating these fallacies"[46] (See Figure 4.2.)

As the emanators and other radioactive nostrums were reaching the peak of their ubiquity in the mid-1920s, the American Medical Association began to mount a campaign to fully medicalize radium and all forms of radioactivity, as a means to better establish professional authority over all aspects of health. After a decade of malign neglect towards the emanators, *JAMA* published in 1925 an article

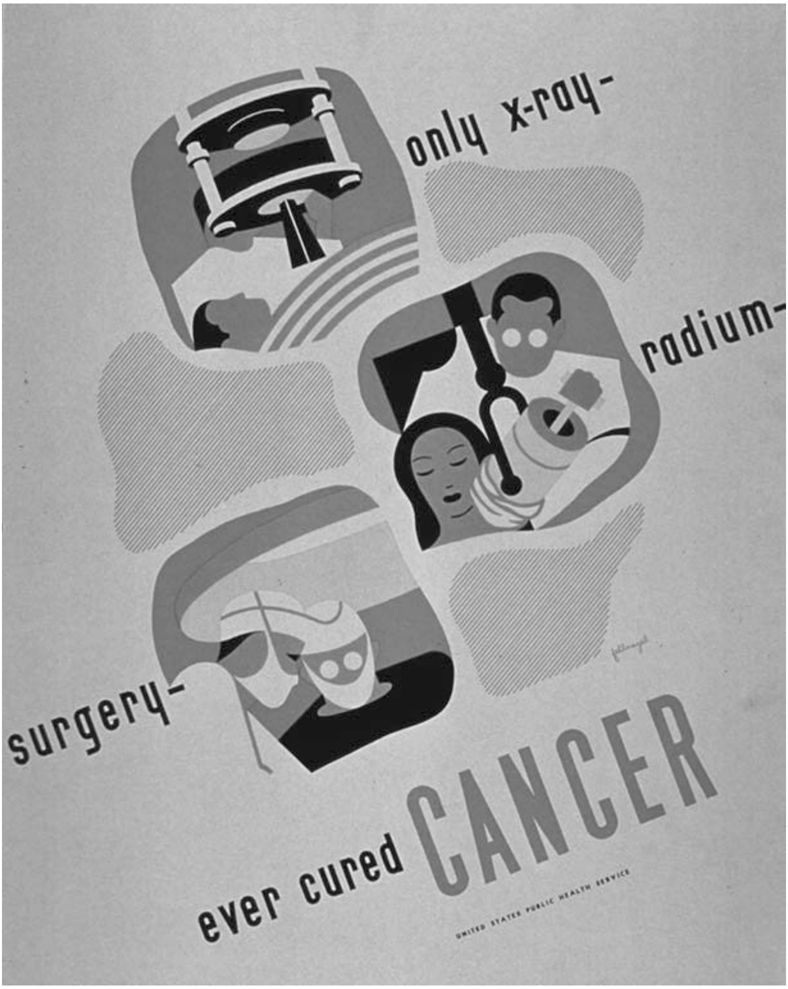

Figure 4.2 "Only X-Ray—Radium—Surgery—Ever Cured Cancer." Most alternative health practitioners and the medical establishment agreed by the 1930s that irradiation was dangerous. They disagreed only about whether it was ever worth the risk.

that recast the them as the point of a very sharp and very dangerous sword: one far more likely to injure health than to restore it.[47] In this formulation, radioactivity was something that was too dangerous, too unpredictable, too inherently malicious and mischievous to be handled by anyone but a clinical specialist. The AMA's Bureau of Investigation began responding forcefully to the hundreds of inquiries they received annually, reminding the doctors who inquired about radium nostrums and unorthodox ray treatments of their responsibility to know better, and in some cases actually suggesting to patients who wrote in that they might be better off with a better-informed doctor.[48] For an organization that put such stress on professional solidarity as the AMA, this was an extraordinary action, but the stakes were high. Control of the nuclear discourse was an existential question, given how closely medical doctors were associated with these energies that were now being blamed for truly ghastly injuries and deaths. This was an appalling conundrum: medical science was not to blame for Byers or any other radium-poisoning victim, and in recent years the only innocents whose suffering could be unambiguously blamed on overexposure to medical radiation were physicians.

To exculpate the energies that were so closely identified with modern scientific medicine, doctors had to show that they had been misused, and moreover, that something had changed to warrant their newly militant stance. "Broadly, the case against pre-War [radium] quacks was one of cruel and unprincipled fraud," summarized one physician in a 1935 chapter on nonstandard x-ray remedies. But "in recent years, the matter has assumed very much more serious and indeed terribly dangerous potentialities. The complaint is not that certain preparations put upon the market are simply fraudulent, but that they *are* radioactive and highly dangerous."[49] Heretofore, physicians had avoided discussion of the dangers of irradiation, lest patients be needlessly frightened away from the already potentially stressful experience of sitting for an x-ray. In countless replies to inquiries from the laity about radioactive products (demonstrating varying degrees of patience with the questions), the AMA's Bureau of Investigation responded that such things "are worthless and if any of them contained enough radium to have any medical effect they would be too powerful to be used with safety by anyone but a physician."[50] Radium was, in this formulation, a heroic medicine, just like mercury, arsenic, digitalis, adrenaline, or narcotics could be—lifesaving, but far too dangerous for unsupervised use. In short, orthodox medical doctors were taking essentially the same tack on the medical use of radioactivity as their naturopathic opposition except that they endorsed its use by skilled professionals. From both ends of the spectrum of medical orthodoxy, then, came the same, frightening message: radioactivity is either *nearly* or *completely* irremediably harmful to living things.

Establishing regular physicians as the only legitimate and safe purveyors of medical radiation was, from the perspective of orthodox physicians, essential for both the public's safety and the profession's integrity. The widely read AMA general-audience health magazine *Hygeia* led the charge, running articles that sought to re-brand radioisotopes and ionizing radiation as too dangerous for unsupervised consumption in any form.[51] Not content with that, Morris Fishbein penned dozens of articles and editorials, columns for *Scientific American*, and letters to editors to drive the message home. He was generally successful: the *Popular Science* article "Radium, Life-Giving Element, Deals Death in Hands of Quacks,"—but not, it went on to make clear, in the hands of a select few physician-experts—was one of many that furthered the AMA rhetoric of radioactivity as a desperately hazardous medicine of last resort. Its sudden emphasis on malevolent aspects of irradiation was typical of this rebranding.[52] The chief medical examiner for New York City, editorializing on the Byers affair, summed up the party line neatly: "Radium, under *rigid* regulation by *skilled* hands and *vigilant* eyes, possesses *certain limited* beneficial qualities in the science of medicine. Unregulated, or administered by the inexperienced, the effect of it may be lethal."[53] The use of five qualifying adjectives to express the usefulness of medical radium, from a medical doctor, was par for the course. Few people had a stronger motive to burnish the qualities of radium than Frédéric Joliot-Curie, the son-in-law of its discoverer and a researcher at the Radium Institute that Marie Curie had established to study its medical properties. Nevertheless, speaking shortly after her death, this was the best he could manage: "At present, radium may embody certain dangers when used for curative purposes. We think we are on the track of minimizing these dangers, perhaps ending them."[54]

To some extent, the medical establishment's campaign against irradiation peddled by irregular physicians included efforts to reassure the public that properly trained physicians could, in fact, manage to force radiation to useful ends. The delegation of radiologists who attended the 1933 World's Fair had adopted two years in advance the (likely unrealistic) goal of dispelling "much of the aura of mystery that surrounds the science of radiology" with their exhibit on radium, x-rays, and other medical irradiations.[55] At New York in 1939, the recent vogue for another sort of energetic ray was exploited in the opening ceremonies, when the first ten cosmic rays to impact a detector each lit a portion of the grounds.[56] Elsewhere at the New York fair, hundreds of people lined up each day to receive free chest x-rays—the price was later raised to $1—complete with analysis by a panel of radiologists, in a demonstration sponsored by the Medical Society of Queens. The exhibit was meant to demonstrate a new and efficient method of taking images on a roll of paper film, but visitors were also told that they would be taking part in actual medical research because anatomical data would be abstracted from the collected images.[57] Twelve percent of those x-rayed were notified later through their physicians of conditions requiring medical attention. Conditioned by fluoroscopy demonstrations and the recurring novelty of commercial x-ray portraiture, participants were reportedly dejected to learn that the images were not available on the spot: a spokesman for the fair reported that visitors thought "that the X-ray machine is a sort of dime-in-the-slot portrait affair which is going to deliver a completed X-ray picture in ten minutes."[58] Otherwise the exhibit held true to the usual tropes of public displays of x-ray images, favoring images of the bizarre or macabre things found by the rays, like shrapnel embedded in a war veteran or a healthy eight-year-old girl missing three upper ribs.

* * *

To the eternal disappointment of the Fishbein-era AMA, its disapproval alone rarely had much direct effect on the practitioners that it labeled quacks and frauds in the pages of its journals. By the 1930s, though, the several government agencies whose jurisdiction overlapped in the realm of consumer goods did occasionally intervene indirectly in an attempt to make radioactive preparations seem less appealing, a fact which itself underlines their persistent popularity. In November 1935, the United States Department of Agriculture's weekly radio program opened by announcing, "Ladies, if your plans for making yourselves more beautiful during the holiday season include a certain radium treatment, you're bound to be disappointed." A shipment of an unspecified cosmetic product, the report continued, had been seized for making explicitly medical claims, which brought it under the purview of the Food and Drug Act. The announcer undermined the "years of study and experience by medical authorities" that the unnamed product had claimed by linking it to the death of Eben Byers, another subject recently much discussed by doctors.[59]

The ground for such a tactic was prepared by the decade of bad press that radium had received by 1935: first as a backlash against its failure to live up to its expectations as a cancer panacea, then as the dial painters' nemesis, and finally as the culprit in the Byers affair itself. But while use of over-the-counter radium medicines (especially ingested ones) went into sharp decline, the underlying appeal of radioactive energy and its long association with the natural and the sanative was a powerful one. As late as 1937, the trade journal *The Glass Packer* was musing about the commercial possibilities of thorium: its radioactive salts, it noted, "are but slightly toxic; they are astringent, tonic, and it is claimed that they can cure certain parasitic skin infections. They are also said to be useful in creams and lotions. The oxide is used in dental creams and powders."[60] Berkeley physicist Leonard Loeb was horrified, declaring it "inconceivable that any firm manufacturing goods to be sold to the public should propose such an insane material merely because of the advertising power of radio-active preparations," a framing that acknowledged the reality of that power even as it deplored its use.[61]

It was probably more effective, however, for opponents of commercial radioactivity to pursue the opposite tack, by undermining the already shaky belief that products labeled "radium" contained any radium at all. The majority of legal actions against the products were forfeitures—literally actions instigated against the products themselves, as for example in the May 1930 case *United States vs. 13 Gross Bottles of Raysol Water*—wherein the effect was to punish the manufactures with the loss of their investment. When the makers themselves were charged with deceptive or otherwise illegal practices, they typically did not contest them, as the fines were light (usually $50 or less) and often suspended. When, however, the Agriculture Department announced that it had surveyed "hair tonics, bath compounds, tissue creams, tonic tablets, face powders, ointments, mouthwashes, opiates, healing pads" and various other purportedly radium-enhanced goods, and found that only 5% of them had appreciable amounts of the element, it likely did more to weaken the consumer trade than any seizures could have, particularly as the finding was reprinted by the Consumer Research Institute and in newspapers.[62]

This was a particularly effective tactic, because the suggestion that "radium" products might not contain their active ingredient paralleled concerns that the ingredient might not be terribly effective. This was a natural consequence of the steadily reduced claims that radioactive products were making, especially compared to the applications that had been imagined in the first flush of excitement over radium. Radium had once (incorrectly) been held to have the power to bleach the skin of the African; now it was being used as the active ingredient in the Narada brand cosmetic line, which made extravagant claims for Narada Liquid Radium Foundation Cream but no hint as to how its purported radioactivity made it more effective than the mundane version.[63] Even for consumers who were willing to accept the totemic power of radium at face value—and the abundance of products makes it clear that there were many—the manifest absence of anything that approached the hyperbolic expectations of years past would have been impossible to miss.

Disappointment with the rays went beyond what little they could do now; it also extended to what they had never managed to do. Few of the more extravagant expectations for the novel energies had materialized by the 1930s. The metal was still surpassingly rare: no enormous deposits had been discovered to make it more generally accessible (or to make anyone wealthy). Radium-luminescence was a passing fad done no favors by the dial-painter scandals. And the promise of limitless energy from a glowing lump of the element (or any radioactive element) in the home had dimmed considerably after three decades. The popularizers still held out hope that someday atomic energies would be liberated on humanity's timetable, but that "someday" was now clearly somewhere off in the middle distance, rather than something that the next day's breathless headlines about radium would confirm.

New Kinds of Rays and Their Reception

There was, nevertheless, news for the public to digest. While progress in medical irradiation had seemed to grind ever so slowly to a halt, in other fields, it continued to advance in fits and starts in the same unpredictable pattern that had characterized its first years. In short order, the American public read about the discovery of superpowerful x-rays from space (Millikan's cosmic rays, announced in 1925), x-ray mutagenesis (via Muller's experiments in 1926), and artificial transmutation of elements via "atom-smashing" (Cockcroft and Walton's work in 1932). When, in 1939, it was announced that Otto Hahn and Fritz Strassmann had succeeded in fissioning the uranium atom, it was news of something very much like progress toward the long hoped-for, too-cheap-to-meter energy source.

In terms of their immediate significance to the physics community, these developments rivaled or exceeded those that had attracted such extraordinary attention to Roentgen, the Curies, and their contemporary investigators. They were reported in a more or less timely fashion by science journalists who, while not as purely sensationalistic as their immediate predecessors, were nevertheless excitable when they imagined the situation warranted it. The overall public reception was muted, though. In its fourth decade, American nuclear culture was large enough to have some inertia: the mass of its collective impressions and expectations was harder for any one announcement to move.

Muller's revelation that x-rays could induce mutations in fruit flies is a case in point. Such mutations had previously been induced by chemical means, and x-rays were already well known to cause sterility by destroying reproductive tissues at sufficient dosage levels. Nevertheless, Muller's work had obvious agricultural applications and many, including Muller himself, reckoned it to be of significance for the then-flourishing eugenics movement. His biographer Elof Carlson wrote that in "tampering with a fundamental aspect of nature," Muller had "provoked the public awe" and become unexpectedly famous.[64] His work was yet another reiteration of the fundamental weirdness of the interplay between radiation and living flesh, by now a firmly established and hardy trope. Lest any casual reader miss the implications, media accounts moved quickly from fruit flies to human beings in their explanations. "The sensational character of Professor Muller's achievement," the science writers of the *New York Times* reminded their readers, "may best be appreciated if we imagine him producing 100 entirely new species of human beings, some with no legs at all, some with arms of unequal length, some with other abnormalities."[65] Indeed, Waldemar Kaempffert, science editor for the *Times* and dean of the young profession of science journalism, predicted that a future historian of "our barbaric twentieth century . . . will not stint himself in praising Muller."[66] Muller's fame, however, was not a manifestation of nuclear culture, but rather the polarizing issues of eugenics and evolution. His "tampering" had been more awe-inspiring for its effects than its causes.

Science fiction, however, proved a somewhat more fertile ground for the seed planted by Muller's work. Two years after the frisson of public interest surrounding his announcement, Ed Earl Repp's well-received serial "The Radium Pool" featured an underground deposit of radium salts that simultaneously wounds, revives, and mutates those who approach it. For 1929, this qualified as a novel twist in the subgenre of ray-stories, which was already becoming a little threadbare from overuse. The crux of the story's action is a confrontation with telepathic frogmen who guard the source of their mutation.[67] The real-world medical applications of radium and x-rays served as a springboard for stories that followed the vital potential of their energies to its logical conclusion: the creation of life. In Alexander Snyder's short "Blasphemer's Plateau," a scientist realizes that the vibrations and energies of the atom are akin to those of living organisms. After some experimentation, he is able to recreate any kind of life by taking the appropriate constituent raw elements and adding the appropriate frequency of "radiant energy." Heedless of the theological objections that are raised, or muttered imprecations about irrationality and hubris, he sets out to create a human from raw materials, a plan that proves no more successful than Victor Frankenstein's was. Snyder's efforts to ground the plot in established science was unsuccessful, and the scientist-as-petty-god premise was shopworn to say the least, but the idea that there was a connection between living tissue and the "life" and "decay" of the radioactive atom was echoed in the brochures of real-world ray-therapists.[68]

The moral implications of substances or energies that could bring about or alter life made for good drama and resonated with a readership that was increasingly experientially knowledgeable of how potent interaction with those energies could be. Lloyd Arthur Esbach's "Dust," starts off as many space adventure stories do, with the windfall discovery of an enormous quantity of radium. Trouble ensues when the concentrated vital force of the radium causes human-sized amoebas to form out of dust and attack the crew. Disaster is averted, but the pilot is forced to ask: "Was the human race ready for so vast an amount of radium? Could men be trusted yet with its infinite power for good and evil?"[69] In another story from the same issue, a terrestrial pilot veers too close to the edge of the atmosphere, and returns vastly improved physically and mentally. "He's been exposed to naked cosmic rays," someone explains, "and as a result he was super-evolved." His enhancements gradually fade, but his antagonist exposes himself to a much longer cosmic ray bath—and returns to earth an ape.[70] In 1932, Warren Sanders put a twist in the usual alien-conquest tale by having patient invaders gently bathe the planet in sterilizing radiation and waiting for humanity to die of old age, and in the wake of Muller's research and the contemporary furor over occupational and medical radium overexposures, he could be certain he was addressing a topic of interest to his readers. But just in case, the editors appended a subheading to the title page: "We are apt, in our busy lives, to forget the tremendous importance of various rays and emanations which beat upon us every second in our lives. Not so many years ago, for instance, it was discovered that those working with intense X-rays were deprived of their reproductive powers. Human animal instinct, thus, can be made sterile at will. Many scientists today hold the view that the vanishing of such huge beasts as the Dinosaur group was caused by the too intense application of ultra-violet rays, as we have them today."[71]

This was not purely speculative fiction: more disruptive than Muller's laboratory-bound experiments was the suggestion that another scientific novelty of the period, cosmic rays, might have a similar effect. These energetic extraterrestrial radiations, first described by the notoriously publicity-friendly Caltech physicist Robert Millikan, helped keep him in the public eye for the better part of a decade—not least because the widely publicized notion that the "death rays of the universe" were fueling evolution.[72] Muller's experiments with fruit flies were replicated to test terrestrial and celestial radiation; they found that between the slow decay of radioactive minerals in bedrock and the constant bombardment of energetic particles from the sky, there was nowhere on earth that was not bathed in some form of potentially mutagenic radiation. This reinforced several popular tropes about radiation: that it was curiously bound up with the processes of life, and that it was especially potent in certain kinds of places. At the same time, it put a new and ominous twist on that association: most people liked their germ plasm more or less the way it was.

But as with Muller's x-ray experiments, the cosmic rays tended to hold the public's attention for reasons having more to do with their secondary effects than any actual interest in the phenomena itself. Physicists had quickly realized that cosmic radiation might shed light on the processes by which stars were born and died; this became transmuted in popularizations into a sort of existential triumph. If indeed a "philosophy of despair and pessimism which sees in the universe only a machine running down" had taken root, Millikan was there to offer hope that this was not so.[73] Since there had not been much extant concern about the fate of the universe, however, this angle did little to commend the rays to further public attention. The question of whether cosmic rays meant the universe was running down was of inherently less interest to the laity than whether terrestrial radium could prevent the body from running down. There was no mania of speculation for cosmic rays, or in fact any of the various developments in atomic structure, that was comparable to what had arisen on the announcement of Roentgen's or the Curies's discoveries. When, in 1932, Millikan (however uncharacteristically, or facetiously) "deplored the public attention on cosmic rays" and suggested that nothing more be said on the matter until more work had been done, he essentially got his wish.[74] They had occupied the headlines in the preceding year because of two spectacular expeditions into the upper atmosphere to measure them. One, a balloon flight into the stratosphere by the Swiss physicist Auguste Piccard, was hailed as a triumph, and Piccard was portrayed as laughing at the so-called cosmic "death rays:" "We were in the stratosphere for sixteen hours and we are still alive," he boasted.[75] The other was a doomed attempt in May 1932 to climb Mount McKinley that left two researchers dead and three more seriously endangered before a series of dramatic rescues. The scientists involved were portrayed heroically in the press, but no particular importance was attached to the nature of their work; their martyrdom for science was not of the same sort as that of a Curie or a dial painter.

There had been fitful progress toward releasing atomic energy through artificial means, rather than waiting for it to trickle out calorie by calorie via natural radioactivity. Ernst Rutherford had artificially transmuted nitrogen into the heavier element oxygen via alpha-particle bombardment in 1917; in 1932, to somewhat more public notice, his former students John Cockcroft and Ernest Walton succeeded in fissioning the stable lithium-7 atom. In early 1939, the news broke that Hahn and Strassman had accomplished the fission of the uranium atom. This was neither a chain reaction nor one that yielded a net surplus of energy; nevertheless, it was promptly hailed in headlines like "Power of Atomic Blast Greatest Achieved on Earth."[76] Yet for the most part, the tone of newspaper and magazine reportage on the progress made toward atomic energy during the 1930s belied the enthusiasm that the idea had previously aroused in the public discourse. "Despite these brilliant beginnings," the *Chicago Tribune* mused in summary of Cockcroft and Walton's work in 1932, "this practical problem may be unsolved for a hundred years or more."[77] The garrulous Rutherford famously called the idea of practical atomic energy "moonshine."[78] This particularly pithy dismissal had a long life in the public discourse, repeated in editorials and popularizations throughout the 1930s. The press' sudden skepticism about atomic energy after decades of breathless anticipation, was not born entirely out of a faithful representation of the sense of the field; Rutherford's view of the practicality of controlled chain reactions was not universally held. Nor was it the result of any sudden sobriety in science reporting. After any number of false starts, the story was simply wearing thin for assignment editors and science reporters. A *NYT* editorial counted the cycles of disappointment: once after radium's eerily energetic nature was first announced, again after Einstein's matter-energy equivalence quantified the amount of power that could be had from a tiny speck of uranium, yet again after the first atom-smashers provoked Rutherford's put-down, and for a fourth time at the close of the decade when the difficulties of separating U-235 became apparent.[79]

For all that relatively few accounts of nuclear fission explicitly invoked runaway chain reactions, the rhetoric of violence deeply infused the presentation of this new atomic technology. What journalists preferred to call "atom-smashing" or "atom-splitting" lent itself naturally to kinetic analogies, but as written they almost invariably took on warlike language. Cosmic rays did not merely ionize atmospheric gases; they committed "molecular murder." Moreover, they did so at the bidding of earthbound scientists: "The 'ghosts of murdered molecules,' 'shot' by 'guns' of radium constantly being fired in the air we breathe, were made to dance tonight in weird macabre rhythm" for the pleasure of attendees at a convention of the American Association for the Advancement of Science.[80] The dynamic of aggression and submission also appeared in the *Saturday Evening Post*'s framing of fission experiments on the U-235 atom: "The Atom Gives Up," declared the headline, when put before the gigantic atom-smashers of Caltech and Johns Hopkins, which "engaged in a blitzkrieg against the uranium atom, hurling against it billions upon billions of atomic projectiles."[81] Even the limitations of intra-atomic violence were addressed with gun language. A *Washington Post* feature on atomic energy addressed the fear that runaway chain reactions would consume the earth by making analogies to faulty munitions, reminding readers that "most atoms are duds," that "fast neutrons overshoot" their targets, and that it was "hard to find the trigger."[82] The constant repetition in these reports of words associated with danger reflected the anxiety about bodily harm from radiations that pervaded the public discourse of the 1930s.

In contrast with the newspapers, science fiction—just reaching the peak of the genre's golden age in the 1930s—continued to play its role as a space in which nuclear aspirations and anxieties could be worked out. Where journalists hesitated to repeat previous decades' extravagant promises for the liberation of atomic energy, the pulps, which had been speculating about radium engines from the start, easily absorbed each new revelation and worked them into their stories. Their readers were, after all, paying attention to science facts as well as fiction. *Science Fiction Magazine* reader Edward P. Sumers's weighed in on a 1941 story about atomic energy, "The Eternal Conflict," by critiquing its departure from "the Atomic Hypothesis" and the example of recent events. Following the logic of the story, he demanded,

> why shouldn't we all be destroyed when a physicist grounds a charge of electricity? And why shouldn't the world explode because a man starts a fire? You know, a fire does destroy atoms—maybe not all atoms, as evidenced by charcoal, but most of them. *N'est-ce pas?* So when U-235

explodes, I'll be wrong, but as far as I can see it won't, it can't, and it never will.[83]

In the pulps, when atomic energies did bring about fictional apocalypses (or threatened to), it was most often because of human inability to properly control them—not, as with *The World Set Free*, because weaponized nuclear energies functioned as intended. And usually that failure to exercise control was rooted in the inherent weaknesses of human nature, rather than a technical insufficiency. This was the case in one of Robert Heinlein's earliest stories, the 1940 pulp novelette "Blowups Happen." Superficially a technically savvy account of the workings of a hypothetical uranium fission reactor, the story is actually a grim meditation on the potential of such a device to drive men mad—not from any radio-neurological ray alchemy, but simply from the strain of being responsible for a device that (in characteristically hyperbolic terms) Heinlein portrays as easily able to crack the planet into two. But the psychological weirdness of "the bomb" (as it is unironically referred to) works another way, too. While recuperating from the stress of bomb-tending at a nearby bar, two technicians have this conversation with their host:

> "Tell me—why do you stick around here when you know that the bomb is bound to get you in the long run? Aren't you afraid of it?
>
> The tavernkeeper's eyebrows shot up. "Afraid of the bomb? But it is my friend!"
>
> "Makes you money, eh?"
>
> "Oh, I do not mean that." He leaned toward them confidentially. "Five years ago I come here to make some money quickly for my family before my cancer of the stomach, it kills me. At the clinic, with the wonderful new radiants you gentlemen make with the aid of the bomb, I am cured—I live again. No, I am not afraid of the bomb, it is my good friend."
>
> "Suppose it blows up?"
>
> "When the good Lord needs me, He will take me." He crossed himself quickly.
>
> As they turned away, Erickson commented in a low voice to Harper, "There's your answer, Cal—if all us engineers had his faith, the bomb wouldn't get us down."
>
> Harper was unconvinced. "I don't know," he mused. "I don't think it's faith; I think it's lack of imagination—and knowledge."[84]

The host's complacency is added to the public's addiction to the power generated by the bomb (13 percent of the country's energy supply) and the uniform refusal of anyone not directly charged with its operation to come to terms with its attendant risks. At the close of the story, the nervous engineers have developed a fuel that will allow the bomb to generate its energy from the moon, a safe distance away from the earth—but the bomb is nearly exploded by one of the plant's many resident psychologists, who has himself been driven mad.

Heinlein's tale, which is shot through with detailed and carefully researched technical passages, was written at a time when "mastery of the atom" seemed, for the first time in 40 years of speculation, at least remotely plausible. The magical thinking that had attended the initial popular enthusiasms for various rays, or the radium craze of the 1900s—wherein the rays were endowed with a certain moral or intellectual agency, to explain their mysterious effects—had largely dissipated. The moral ambiguity here derives from human fallibility, and Heinlein's deliberate use of up-to-the-minute physics in the story signals only that nuclear energies are, finally, a reality that will test those human foibles on a potentially apocalyptic scale. In that regard, it is an unusual story only for its quality of writing; the same ominous tale had been told hundreds of times already. Even "Jack Armstrong, the All-American Boy" of radio serial fame was experimenting with U-235 by 1939.[85]

Medical Irradiation Comes of Age

Medical encounters with x-rays were, by the 1930s, fairly commonplace. Widespread electrification, the use of portable machines in rural areas, and the quickness with which the x-ray diagnosis of suspected fractures and various other ailments became the standard of care meant that, by the time irradiation came to be perceived more generally as a physical threat, most Americans had at least some sort of reference point against which to measure the horror stories about dial painters and radiologists. Moreover, the mid-century clinical encounter was radically different in experiential terms from its turn-of-the-century equivalent. In his breezy and popularizing memoir *These Mysterious Rays* (1943), radiologist Alan Hart described what a typical patient might experience during a visit to his modern x-ray therapy clinic. At the end of the treatment, the patient "has heard nothing, felt nothing. In fact, a good many of our patients cat nap during their treatments. Most city bedrooms are noisier and far more uncomfortable than the treatment room. To a visitor expecting the horrendous it must all seem very drab and uninteresting. Of course," Hart added, "older machines were not so quiet and convenient."[86]

Those older machines, which used low-vacuum Crookes tubes, were fragile and finicky compared with the hot-cathode tubes that began to supplant them in the mid-1910s. This had been the first in a series of transformative changes to the overall experience of x-raying which, taken as a whole, effectively "domesticated" the x-ray machine, transforming it from an unreliable, smoking, sparking spectacle into one unobtrusive piece of clinical equipment among many. Older machines were not replaced instantaneously, of course, but by 1926, pioneer radiologist Henry Pancoast could declare that the "epoch" of the old gas tubes was nearly at an end: patients were by then far less likely to encounter bedside gasoline generators powering the tubes, uninsulated live wires throwing off sparks and ozone, or the other especially vivid elements of gas tube era technology.[87] "You modern chaps who have never 'baked' a tube and who have never juggled lightning with the tube in a wooden clamp, spraying the room like a broadcasting station, cannot realize what those martyrs of yesteryear have saved you," retiring radiologist F. S. O'Hara chided his younger colleagues in 1932. "Trouble? Why the handling of an x-ray apparatus of those days was nothing else. Like the early automobiles, if one thing was right the others were wrong."[88] His tongue-in-cheek scorn for the "modern chaps" whose machines worked as advertised, without heroic measures, underscores how thoroughly the apparatuses had changed in the decade or so that preceded his essay. Physicians got their roentgenographical training on the job, often through nothing more than trial and error, and the trouble they had was magnified by the complexity and fragility of the first-generation apparatuses. Radiology textbooks aimed at MDs with no experience whatsoever were published as late as the 1940s; Alan Hart frankly admitted learning to operate his machines and wield his fluoroscopy screen "literally . . . with book in hand."[89]

F. L. Pengelly, who represented the Victor X-Ray Corporation in the western states in 1914, recalled that "every installation meant staying on the job until the customer could make *fairly* satisfactory x-ray exposures and could process the plates *reasonably* well. You can appreciate that the difficulties encountered with beginners were sometimes discouraging." This was a diplomatic way of putting it: doctors burned out tubes prematurely, allowed their developing materials to become contaminated, and summoned technicians from hundreds of miles away to make minor electrical adjustments. Pengelly serviced the machines of rural doctors who had impressive cabinets but no heat or running water.[90] At times the ad hoc nature of doctors' strategies for dealing with their temperamental machines bordered on the absurd: faced with a machine that balked in humid weather, one doctor left gingersnaps inside the case of his static generator as a makeshift hygrometer. He fared better than the Pittsburgh doctor who tried using calcium carbide as a desiccant, which caused an explosion when a stray electrical discharge touched it.[91]

Incidents like these embarrassed doctors, even when the effect was not really detrimental to the patient's care, and through the power of the purse and constant commentary in their journals, they pressured equipment makers to make machines that were more reliable, less temperamental, and above all less dramatic. By the late 1920s, the effect of that pressure could be seen not only in the products themselves, but also in the language that appeared in catalogs comparing the newer, more domesticated machines with the previous generation. Announcing an improved transformer in 1926, Acme International guaranteed that this model would suffer none of the problems of the previous model, which included "extremely noisy" operation, "nauseating" gases, "long straggling sparks . . . always present, resulting in a flaming arc," and an "ever-present fire menace."[92] Two decades earlier, by contrast, the makers of the Aristo 1907 model had pointedly boasted of its "flame discharge of 3 inches [which] proves the volume or amperage to be immense."[93] That kind of language was neither anomalous nor ill-considered: for all the anxiety it might produce in a patient, a robust electrical discharge was a point of pride for doctors, who were not only able to make better images with the more intense rays that accompanied it, but gained the satisfaction of having forced a notoriously temperamental machine into temporary submission.

The second generation of x-ray technologies were created with the aim of preserving and enhancing the dignity and authority that early-adopting physicians had sought from their first machines. This much can be read directly from their advertisements. If patients were frightened by the buzzes and sparks of an older machine, Acme was eager to assure doctors of its new unit that "being positively noiseless, it is pleasing to the patient in that all cause for fear is removed."[94] If children were afraid of x-rays, then 1928's portable machine model was called for because "[e]very Roentgenologist knows that occasionally a suffering child is terrorized at the sight of the equipment in the X-Ray laboratory. To be able to conduct a fluoroscopic examination, or to make a radiograph, with the child in his bed is often a great advantage."[95] If the heat generated by machines was uncomfortable, and the electric fans used on older machines ineffective and dangerous, then a built-in cooling system new for 1928 was what was called for.[96]

Every element of the x-ray apparatus underwent at least one major improvement in the 1910s and 1920s. Gas tubes gradually yielded to the more rugged and adjustable hot-cathode tubes. Glass photographic plates were replaced by film of steadily improving responsiveness and longevity. Near-universal electrification rendered the static generator obsolete, and with alternating current entering the clinic, Ruhmkorff and Tesla coil apparatuses were succeeded by the "interrupterless" transformer that permitted much higher voltages and thus worked best with the newer, hardier tubes. The Potter-Bucky diaphragm, a grid of lead wires that blocked stray radiation and sharpened images (thereby shortening exposure times) was invented in 1920. In medical terms, the sum effect of these improvements was to permit shorter exposure times, clearer images, a lower overall radiation dose, more localized therapeutic irradiation, and a wider range of frequencies. Between those advancements and refinements in radiological technique—deliberately burning patients was no longer best practice by the 1930s—patients in the latter era saw far fewer things go wrong.

These improvements were visible to Americans whose trips to the doctor (or, increasingly, to dentists or certain kinds of alternative practitioners, especially osteopaths and chiropractors) required diagnostic or therapeutic irradiation. But other changes to the way that x-rays were generated attracted attention, too. Though relatively few would be treated by them, the public was kept well informed of the trend in medical research toward superhigh voltages and giant apparatuses that were being constructed for radiotherapy and industrial applications. Here was heroic medicine indeed: while the early machines had been imposing enough at cabinet size, the special purpose high-voltage apparatuses required holes to be cut in ceilings just to accommodate their tubes. The inflationary rhetoric would have been hard to miss, as in this Science Service radio broadcast from 1938:

MR. [Lauriston] TAYLOR [National Bureau of Standards]: For some time, 50,000 volts seemed daringly high.

MR. [Watson] DAVIS [Science Service]: That's enough to photograph the human bones, isn't it?

MR. TAYLOR: Plenty. Scientists began photographing the human skeleton almost as soon as Roentgen announced his discovery. . . . That only takes a few thousand volts. Well, seven years ago, scientists were stepping X-rays up to 300,000 volts and they thought that was high-power. They could penetrate four inch steel with that.

MR. DAVIS: And now they talk in millions of volts.

> *MR. TAYLOR*: Exactly. So, you see, we have a sliding scale of thinking X-rays high-powered. But today when we say high-powered or supervoltage X-rays we mean, oh, from 300,000 volts to one or two million.

The discussion proceeded to deploy more giant or infinitesimal numbers: x-rays are a *trillionth* of an inch long, electrons in such a tube move at *150,000 miles a second*, the equipment used to measure the rays' potency weighs *over a ton*, the *1,200,000* volt tube is *27 feet* long. Lest the length not sound quite as impressively large as the other numbers Taylor cited, he immediately contrasted it with a mundane three-inch dental tube that he had brought with him.[97]

The turn toward describing x-rays and radium with big numbers, also commonplace in reports about atomic energy and "atom-smashers," amounted to a demystification of those energies. Previously, the only reliably quantified aspect of either was the market price of radium: popularizers and editors knew that the significance millions of dollars could be registered in ways that billions of electron volts would not. The energy locked away in radioactive nuclei, or carried in an x-ray photon, or the velocity of alpha particles, had generally been described in qualitative, if hyperbolic, terms: it sufficed to say that they were "titanic," "devastating," and "speedy." The turn toward describing these energies using large numbers was one of the effects of the professionalization of science journalism; quantification had been explicitly endorsed by the National Association of Science Writers (NASW) as a means to improve accuracy. With respect to radiation research, it had the effect of reinforcing the new notion that the rays were not so much super*natural*, as they had sometimes seemed, but rather existed on a super*human* scale. This, in turn, fit neatly with the argument promoted by orthodox physicians, that only a select group of experts, using highly specialized equipment, could bring them to heel.

Radium, which for all that explicit quantification still connoted arbitrarily vast amounts of energy, was used as a point of reference for the new super–x-rays of the 1930s and 1940s, although they were generally presented as coming up short. This was not so much a direct physical comparison—the alpha emission of radium and high frequency ionizing electromagnetic radiation were, of course, different and essentially incommensurable things from the perspective of a physicist or a physician—as it was a way of referencing the relative medical usefulness of each. Notwithstanding the meager return on the emotional investment that had been made in radium as a cancer cure, high-voltage x-rays were presented as failing to meet even that standard. Davis asked Taylor, rhetorically, if such powerful tubes might become a replacement for radium, and got this crisp response: "No indeed! That's emphatic!" A newspaper story on W. D. Coolidge, the researcher behind several innovations in high-voltage radiography, elaborated grimly on the risks of even experimenting with such enormous voltages: "Man, in his effort to equal the power of radium, is locking himself up in a lead-lined room, encaging himself within a cabinet of thick lead and submitting himself to the dangers of high electric currents such as he has never reached before." Coolidge, described overseeing research on a million-volt apparatus, moves with all deliberate caution: a willingness to be martyred was, by 1928, no longer a heroic attribute in a scientist. Yet for all his progress, lavishly detailed by the friendly journalist, "he has succeeded, so far, in attaining only one-half the power that lies within a fraction of an ounce of radium—nature's most remarkable element."[98] In these sorts of articles a distinction between the rays' *power* and *potency* was introduced: Caltech's million-volt "giant cancer tube" produced the "most powerful rays" which were "equivalent to [the] entire world['s] radium supply."[99] Accounts of extraordinarily powerful radiation curing a few desperately ill people of a particular disease at a few select sites did create not an optimistic zeitgeist, however, and the differences between Robert Millikan's apparatus and the family doctor's would have been impossible for patients to miss. These million-volt "siege guns of science" might represent a "new and dramatic chapter" in the story of x-rays, but they also closed the book on what most patients could hope to gain from irradiation.[100]

Conclusions

By the end of their first half century, x-rays as experienced by the American public had effectively become domesticated. Giant, gun-like apparatuses existed in functionally inaccessible hospitals and laboratories, and super-rays rained down from space, but in everyday encounters they were an ever subtler manifestation from an ever more understated machine, operated by ever more specialized and professionalized workers, and in ever more regulated circumstances. The rays themselves had become thoroughly dangerous things in the discourse: x-ray vitalism had died with the martyrs. But the danger was of a knowable and controllable sort: the rays originated, after all, from machines. Specifically, from the sort of machines that had become closely associated with the cool competency of the ultramodern scientist, the dramatic backdrop to magazine photographs of Robert

Millikan and Arthur Holly Compton. This was an association that had been decades in the making. From the moment they were announced to the world, acquiring any sort of x-ray generator had required an investment of patience, technical expertise, or money beyond the reach of most amateurs or entrepreneurs. As a result, the points of physical contact between nonscientists and the rays themselves were funneled through a relatively small number of channels: portraiture, exhibitions and museums, medical and quasi-medical settings, beauty shops, and so forth. In other words, there was an institutional component to the process by which Americans became irradiated. Radiation had almost always involved an external agency to regulate it, and this became more and more true as the years wore on.

Exactly the opposite was true with radium: for its first decade in the public eye, it was understood virtually by definition to be unobtainable, an aspect of its public profile that only gradually receded enough for consumer goods containing infinitesimal or imaginary amounts of the substance to appear. Because they did appear, however, and because of the pressure that manufacturers of such goods faced both from the medical establishment and government agencies, the distribution of radium and other radioactive substances (or their imitators) tended to be decentralized. A patchwork of mail-order, local-agent, door-to-door, retail, and physician-referral sales comprised the means by which such substances found their way from ephemeral Denver- and Pittsburgh-based wholesalers and into consumers' hands.

As a function of that rather more democratic form of distribution, and the attendant advertisements, radium did not reflect on the scientific establishment in the same way in 1940 as it had in 1904. If Henry Adams had once seen it as a "bomb" thrown at the old guard of science, it was latterly depicted as the antagonist itself: knowledge of nuclear emanations, taken by force with "siege guns" and by "smashing" the recalcitrant atom, were the hard-won spoils of battle. Where physicists might occasionally gain ground, physicians fared worse, winning only Pyrrhic victories. Radium, more and more directly personified in the press the more "evil" it became, lashed out against its captors, burned those who embraced it, and killed its own "mother." Where x-rays had *technicians*, it had *handlers*, and when it was lost, the "radium hound" was called in to track the prey. Radium was connotatively (and in dozens of places like Radium Springs, Georgia, literally) inscribed on the American map: it was a Western phenomenon, conjuring up alpine vistas and mountain springs, and was scarcely discussed for long in any context without a nod to its geological origins.

It resided in a geographic region, while x-rays were better understood as belonging merely to specific rooms, such as the doctor's office or the physics laboratory.

Yet radium was not actually any sort of a threat to any American, except for a self-selected few medical or scientific personnel. Patients could refuse treatment by it, if by chance their physician had access to it; anyone else might have trouble laying hands on it in the first place. Why, then, did radium's presentation sour so quickly and dramatically? Radium entered the public discourse as a bizarrely powerful mineral, "vital" in that it gave off energy seemingly inexhaustibly, but alive only in a metaphorical sense. Its subsequent rhetorical transformation into a thing that was inextricably bound up with human life, and then into something deeply antagonistic to it, was the result of several distinct ways that it was part of the experience of the typical health seeker. When it was, for the health-conscious, almost entirely absent—as was largely the case during the first decade after its discovery—it was to the interested public a fascinating physical oddity but not a medical one. As it began to become more commonly available at the clinic—and, to a much greater extent, when it became part of the spa culture—it acquired the characteristic of being not merely vital, but vital to the processes of life. When, during this period, spa-water sellers compared water without radium emanation to air without oxygen, they meant it literally. By the late 1920s, roughly the peak of the element's availability on the medical and consumer marketplaces (and here ersatz radium products must be accounted for as well as the much rarer genuine ones), patients had finally gained enough experience with the substance on an experiential basis for that familiarity to begin to breed contempt, or at least potential disillusionment. Demonstrated dangers (which had been common knowledge since 1903) could be and were offset by expectations of miraculous benefits, but those expectations could not be maintained in the face of the underwhelming reality of radium nostrums. Only because the laity had had actual contact with radioactive substances (or believed they had), could the experiences of Marie Curie, Eben Byers, and the dial painters start to gain a real foothold in the discourse.

The changes in sentiment toward radiation did not mean that nuclear culture in the United States had dissipated, of course; merely that it had changed its orientation. Returning to Kirk Willis's capsule definition of the term, the "knowledge, imagery, and artifacts" of atomic emanations, we find that there were more of all three at the low point in their popularity than at any other point. In learning to see radiation as fundamentally and inherently dangerous, and in actively reconceptualizing what kinds of people (if any) could be relied upon to remediate the risks it posed, American nonscientists were establishing the foundation for the culture of what, after Hiroshima and Nagasaki, would become the second Atomic Age.

Chapter 5

Toward the Second Atomic Age

In 1899, the *American X-Ray Journal* alerted its readership—mostly, the physicians who were bringing the discipline of radiology into existence through trial and error—to the potentially lucrative sideline of x-ray hair removal. The appropriate dose for removing unwanted hair from female patients could be generated, the article said, by placing the area in question a foot from the tube, for ten minutes. (More than that would "try her patience.") Three or four "séances" would suffice for young women; older women with tougher hair might require eighteen.[1] The article specified an amount of current, but not the kind of tube that should be used. Even by the rudimentary standards of the day, these technical instructions amount to nothing more than a vague gesture at the amount of radiation that should be absorbed; doctors with generators could figure the details out themselves.

A few years later, the journalist Cleveland Moffett related for the readers of *McClure's Magazine* the story of his meeting with Pierre Curie. After an amiable conversation, establishing just what radium was and was not, Curie invited Moffett into a darkened laboratory.

> After we had been in the darkness for some time M. Curie wrapped the radium tube in thick paper and put it in my hand.
>
> "Now," said he, "shut your eyes and press this against your right eyelid."
>
> I did as he bade me and straightaway had the sensation of a strange diffused light outside my eye. M. Curie assured me, however, that the light was not outside but *inside* the eye, the radium rays having the property of making the liquids of the eyeball self-luminous, a sort of internal phosphorescence being produced.[2]

Most twenty-first century readers will shudder at the thought of three hours spent a foot away from a bare x-ray tube, or at having a powerful alpha emitter pressed against the eyeball until the vitreous humors glow. It is tempting, of course, to simply explain away the eerie nonchalance of these actors by saying that, for the most part, they knew no better. Yet many of their contemporaries, equally innocent of latter-day radiobiology, found the very idea of invisible energies horrifying, much less the prospect of being subjected bodily to them. If we discount these reactions, too, as simply uneducated guesswork (albeit of a healthier sort), then we still have to account for the extraordinary allure that these new energies had for a populace otherwise quite capable of ignoring the pronouncements of its fledgling scientific establishment. There were other (much milder) popular science fads around the turn of the twentieth century: one could buy books that conjured with the fourth spatial dimension, or liquefied air, if x-rays didn't appeal. Was "radiomania" simply a passing fad that happened latch onto something that turned out to be of real importance?

In fact, as the preceding chapters have shown, nonscientist Americans were rarely so poorly informed about the novel energies as we have usually assumed. Even at the very outset, x-rays were made comprehensible by analogy to sunburns, or photography, or light bulbs, or spiritualism. A gram of radium could be explained as a mineral concentrate of so many tons of burning coal, or so many millions of dollars. There has been a tendency among historians to ascribe perfect ignorance of these energies to Americans at the start of the next atomic age, and to assume that the formative moments of American nuclear culture all occurred in August 1945. But the great stores of preexisting knowledge about nuclear emanations were not vaporized by the atomic bomb, nor were long-evolved judgments about them entirely maladapted to the postwar environment.

The Second Atomic Age

Paul Boyer put the first five years of that post-Hiroshima nuclear culture under a microscope in his 1985 book *By The Bomb's Early Light*. His thorough survey draws on everything from Atomic Energy Commission pamphlets to cereal boxes in order to frame American nuclear culture in those unstable years. In the introduction, he reports his own surprise at "how quickly contemporary observers understood that a profoundly unsettling new cultural factor had been introduced." Historians, he is saying, rarely find that their subjects really understand the forces that are being unleashed around them, and even less frequently have any good perspective on how things will unfold. But the pages of *Life* and *Reader's Digest* from the late 1940s are full of uncannily accurate predictions about what nuclear energies would mean for American society going forward.

At least some of that prescience must be attributed to the fact that Boyer's account actually depicts the simultaneous eruption of three long-rehearsed themes of the first atomic age. The first was a recapitulation of the mania for nuclear novelty that had attended the unveiling of the new energies at the turn of the century. The book begins with a none-too-rhetorical question meant to measure the sudden and permanent reality of uncontrolled nuclear fission in 1945: "How does a people react when the entire basis of its existence is fundamentally altered?"[3] With surprise, of course, but also with a curious playfulness: with song lyrics, sexual innuendo, nervous humor, and an insatiable appetite for the next day's newspaper full of atom-themed stories. In short, "the people" reacted just as they had in 1896 and 1903.

Almost simultaneously, fears of nuclear annihilation arose as the realization took hold that the devastation visited on Japan could also be turned on American cities. In part, this was fear of the unknown; in part, it was fear informed by reports that made clear just how complete the annihilation of Hiroshima and Nagasaki had been. And, as Boyer emphasizes, some of that fear was deliberately fanned by those who could speak authoritatively on atomic matters because it was "useful," in that a population sobered by the destructive potential of nuclear weapons was politically tractable. Just as orthodox and alternative physicians had sounded the same dire note for different reasons on the dangers of irradiation, military spokesmen and folk singers alike sought to dampen the giddy optimism that had been the natural reaction to the bombs' role in ending the war.[4]

In large part, they succeeded. By the end of the 1940s, Americans were finding some refuge in atomic futurism from their newly revived atomic fears. In the "techno-atomic utopia" envisioned by the science journalists, the now-demonstrably unlockable energies of the nucleus would soon power automobiles, control the weather, green the deserts, and accomplish all manner of other miraculous ends. Boyer noted that it took only a single day after Hiroshima for one paper, the *Milwaukee Journal*, to fill its pages with these sorts of "amazing predictions that would soon become clichés."[5] But atomic cars and the other nuclear novelties presented that day had in fact been clichés for decades already: a British popularizer rolled his eyes in 1910 at his American counterparts' insistence that someday soon "heavy freight trains will be hurled over the lines by the action of a single grain of radium."[6] The *Journal* article that ran on August 7, 1945, would have been every bit as familiar and only marginally less plausible had it appeared on August 5.

For all the apocalyptic majesty of a mushroom cloud, and all its terrifying implications, the "fundamental basis" of American nuclear culture did not change with the demonstration that atomic energy could be liberated on demand. The underlying equation that measured risk against reward and expectations against accomplishments did not change, even as several of its terms were substantially altered, yielding new results.

Perhaps the most substantial difference in nuclear culture after the war were the various and contradictory interventions of the federal government, which had not been significantly involved before radioisotopes became a matter of national security. Military triumphalism was only a minor theme in the government's abruptly voluminous contributions to the nuclear discourse; while generals and defense contractors argued privately about the possibility of "winning" full-scale exchanges with other nuclear powers, the message most likely to filter down to the general public was the one taught by Bert the Turtle.[7] Stoking public apprehension about hostile nuclear weapons quickly reached a point of diminishing marginal utility, however, and had to be counterbalanced. In 1953, President Eisenhower drew attention to the peaceful applications of nuclear energy in a speech before the UN General Assembly, and promised to share American accomplishments in those fields with the world. The principal aim of the "Atoms for Peace" program was to placate the United States' allies, who were worried that American brinkmanship would lead to a nuclear war being fought for (and hence in) Europe. But the address had domestic currency too: Eisenhower knew that the horns of the "fearful atomic dilemma" were pointedly felt at home.[8]

The nuclear physics and engineering communities of the 1960s burgeoned with recently minted PhDs, thanks to Cold War funding of science education. They had all sorts of ideas about peaceful applications of atomic energy, and not merely the mundane generation of electricity. Nuclear submarines and carriers quickly became reality, albeit a reality at a safe geographical remove from most Americans; atomic cars, planes, and rockets were scrapped in large part because they couldn't be kept at a safe distance.[9] Controlled fission reactions were tolerable, even in a ship of war, but what about an uncontrolled chain reaction—a nuclear detonation—in the name of peace? This was the idea behind Project Plowshare, a series of proposed and actual nuclear explosions intended to develop their use for excavation, mining, and other civil engineering purposes. As Edward Teller, one of the most vocal advocates for Plowshare noted, the one thing no one contested about nuclear explosions was their ability to "make a hole in the earth," and that from there it was merely a matter of repetition to make a harbor, or even the otherwise infeasible Nicaraguan version of the Panama Canal.[10] Plowshare scientists even explored atomic-based climate control: 20 "relatively nonradioactive" bombs in the megaton range might be enough to disperse or divert a hurricane, it was thought.[11] (Even this, though, had been anticipated in almost every detail in by Frederick Soddy in his massively popular 1909 general-audience book *The Interpretation of Radium*. "If we can judge from what our engineers accomplish with their comparatively restricted supplies of energy," he wrote, then those same engineers, given access to the energy that resided in the nucleus, "could transform a desert continent, thaw the frozen poles, and make the whole world one smiling Garden of Eden.")[12] In and amongst the frequent tests of nuclear weapons, the 27 Plowshare tests conducted between 1961 and 1973 might have gone unnoticed, or even been celebrated by the communities they were intended to assist. But a groundswell movement, initiated by unaffiliated scientists and joined by what became the broader antinuclear movement, succeeded in publicizing the tests and associating them with the hubris and overreach of more militaristic science.[13]

The tide turned against the peaceful atom for two reasons that are not readily apparent without an appreciation of prewar nuclear culture. The wonders Eisenhower and Teller predicted for the harnessed atom had been promised many times before—and the promises of yesteryear had been more inspiring than Teller's vision of atomic backhoes for earthmoving. But the drawbacks of exposure to radiation had been evident to the public for decades, and seemed to keep reoccurring. When Navajo uranium miners realized in the 1950s that the cancers they suffered were caused by radiation from the ore they were working, their reaction and that of those who read about them were informed by the stories of the radium dial painters—and also of a longstanding concern in labor circles, dating back to the 1920s at least, about the particular hazards posed by radioactive ore.[14] In short, little if anything in the post-Hiroshima world had suggested that scientists had accomplished *mastery* of the atom, so much as discovered a means of setting it off.

As the place where the uranium mining happened, and more significantly as the site of most of the country's nuclear weapon tests, the western United States had become more connotatively associated with radioactivity than ever. But, as the public was repeatedly reminded, those radiations refused to stay confined to weapons ranges and mine shafts. What had once been a local treasure became, over the second half of the twentieth century, more like a nationwide radioactive malaise, as new and less geographically specific environmental hazards, like wind-borne fallout from atmospheric bomb tests, presented themselves. This, too, was a lesson learned as much in the first atomic age as the second. When the bottlers of Mountain Valley Spring Water responded to concerns in the early 1950s about nuclear fallout by prominently touting a recently installed glass cover over their main spring as a foolproof means of delivering water that was absolutely *untainted* by any radioactive contaminant, they were displaying a sensitivity to sentiment about the subject that had, decades earlier, led them to tout the *presence* of natural radioactivity in their waters (and to note its absence in those of their competitors).[15]

Between 1959 and 1970, the Greater St. Louis Citizens' Committee for Nuclear Information conducted its Baby Tooth Survey, which measured the amount of radioactive strontium-90 in children's teeth. The name of the committee itself suggests the growing dissatisfaction with the relatively anodyne statements on nuclear safety being issued by the "oracles speaking 'ex cathedra' from the Atomic Energy Commission."[16] Schools and churches were enlisted to get word of the program to parents. Its purpose was made clear to all participants: to indirectly measure the concentration of fallout isotopes in the food supply. The results of the survey, which were announced periodically, helped build political pressure for the atmospheric nuclear test ban treaty ratified in 1963. The almost immediate decline in the strontium-90 levels measured in teeth garnered attention, too, as newspapers repeated experts' assurances that children were consuming fewer radionucleides with each year following the ban.[17]

The influence of the Baby Tooth Survey was what amounted to cheerful news in the nuclear discourse of the 1960s; it put a hair or two of the atomic genie back in the bottle. But the consensus view of radioactivity as a chronic environmental threat came roaring back in the mid-1980s with the recognition of accumulated radon as a significant public health threat. In 1984, Stanley Watras began setting off radiation alarms when *entering* the Pennsylvania nuclear plant where he worked as an engineer. The cause was eventually determined to be perilously high levels of radiation from radon that had built up in his home, as well as many others in the area, which rested on uranium-rich bedrock. The resulting alarm received sustained nationwide attention in the media, with heavy ironic emphasis placed on the fact that Watras was apparently less at risk while working at a nuclear power plant than while at home. The juxtaposition made neither place seem particularly safe. The utility company that owned the plant Watras worked for ultimately decided to pay for the remediation of the radon accumulation in his home, reasoning that negative publicity about natural radioactivity would be just as bad for business as a crisis involving artificially produced radiation.[18]

They had reason to be concerned. Until the advent of commercial nuclear power with the opening of the Shippingport Atomic Power Station in 1957, the focus of public anxieties had been on mushroom clouds rather than meltdowns. The first few power plants, including a few experimental reactors that predated the Shippingport reactor, were opened to more fanfare than alarm, but the rise of the nuclear power industry coincided too closely with the rise in public concern over fallout from atmospheric testing of weapons, and the honeymoon was brief. The antinuclear movement that had coalesced out of fallout fears and the resurgent environmental consciousness of the late 1960s succeeded in canceling, delaying, or curtailing the construction of a number of subsequently proposed plants.[19] The electricity produced by a working nuclear plant was indistinguishable from that of a coal-burning plant, but the potential dangers that nuclear opponents like Ralph Nader could point to were vivid and compelling. By 1979, the year of the partial meltdown at the Three Mile Island plant, the sense of riskiness that attended nuclear power was so ingrained in the public mind that the incident itself was famously anticipated by the just-released movie *The China Syndrome*, in which a shoddily maintained nuclear plant threatens to irradiate an area "the size of Pennsylvania." All but permanently politically poisoned, the commercial nuclear industry did not see another plant approved until 2012.

* * *

By the 1980s, then, many of the predictions of the 1890s had been realized. The energies locked away in radium (and its more usefully fissionable neighbors on the periodic table) could be released on a human time frame, and if the resulting power was not too cheap to meter, it was at least cost-effective. Nuclear medicine, which was now oriented toward relatively tiny doses of carefully selected artificial radioisotopes, was now less dangerous than the diseases it was used to treat, and no longer restricted by radium's relative scarcity to the very wealthiest or sickest patients. Even some of the most outlandish speculations from those first few fevered years had come true, after a fashion. In 1896, the *New York Times* had jokingly suggested that doctors might use x-rays to read patients' minds; by 1996, neurologists could watch the brain at work in real time through functional magnetic resonance imaging.[20]

Yet even as practical applications of the now no-longer-novel energies proliferated, the public sentiment toward them narrowed. Radiation in prewar science fiction was often presented as a Promethean fire that lighted the way to adventure; in the literature and films of the postwar era, it was fire of a more Satanic sort. The extensive canon of postwar radioactive movie monsters, mutated or maddened by atomic tests or nuclear waste, needs little introduction: even the casual connoisseur of postwar popular culture will know that radiation transformed a dinosaur in *Godzilla*, ants in *Them!*, and a socialite in *Attack of the 50 Foot Woman*. More prosaically, but also more frighteningly, it mutated the natural political order of things in films like *On the Beach*, *The Day After*, and *Fail-Safe*, among hundreds of others. This category of films, plotted around a nuclear crisis at the very least but more typically a full-scale atomic war, were what the science fiction community called "awful warning" stories, and they were appropriate to the prevailing mood. Very few postwar works of any sort have been willing to treat radiation with the same lighthearted or optimistic tone that was so common in the pages of the prewar pulps: extremely dark comedies like *Dr. Strangelove* were as close as any came. This is true even in comic books, which inherited much of the readership lost by the decline of the sci-fi pulps. An informal census of the golden age of superhero comics finds more radioactive villains than heroes. Even the good guys transformed by radiation bore the scars of it: the gamma rays that made the Incredible Hulk, for example, also tortured his alter ego, the hubristic physicist Bruce Banner. Superman appeared in comic books in 1938, but his radioactive Achilles' heel, the glowing green mineral kryptonite, did not appear on those pages until 1949.

Speculation about new applications of radiation in the second atomic age tended toward the macabre, or at least the bellicose. H. G. Wells had foreseen the atomic bomb; everything from RAND Corporation white papers to Kremlin press releases heralded the arrival of the neutron bomb. These weapons, which were never a substantial part of the United States' vastly complicated nuclear arsenal, were designed to kill human beings as much as possible with radiation rather than heat, pressure, or debris. This was enough to make them a fixture in popular culture that was otherwise quickly becoming inured to the difference between a kiloton and a megaton, or the A-bomb and the H-bomb. Photographs of Hiroshima and

Nagasaki reduced to rubble looked superficially like photographs of Dresden; for that matter, so did burn victims from both places. But within days the lingering, plague-like deaths from radiation sickness that distinguished the victims of nuclear attacks had been seared into the collective understanding, and the suffering of those who survived the initial attack became an idée fixe in the discourse of the postwar period. Nevil Shute's *On The Beach* (1957) is set entirely in the aftermath of a nuclear war in the Northern Hemisphere, and deals principally with the slow, unlovely deaths from radiation sickness of the inhabitants in the Southern. *A Canticle for Leibowitz* (1960) spans 11 centuries of irradiated post-apocalyptic history and lingers on the hopelessness of the grotesquely mutated and suffering quasi-humans that populate the earth. In neither book does a bomb explode, until the very end of *Canticle*, when a second and more permanent nuclear holocaust is almost a relief. The horror of both, and many other fictional and speculative works of the second atomic age, derives entirely from the prospect of life in a world made permanently insalubrious by the indelible presence of radiation.

The First Atomic Age in Retrospect

From the perspective of the pre-Hiroshima world, then, the "atomic age" that followed looks almost monochromatic, or at the very least confined to a much narrower range of the emotional spectrum, between wariness and terror. Contrast that limited palette with the connotative richness of the first half century of American nuclear culture. "Radiomania" as first experienced was not entirely, or even principally, a matter of sober awe. Instead, it was an invitation to speculate on a future in which the twentieth century would become more unlike the nineteenth than the nineteenth had been like the first. The eerie lights and alchemical rocks brought forth from the laboratory at that moment were not just hints of what might come. They were the heralds of a completely unknown future: the light of a scientific dawn, for good or ill.

Before he was drafted into the war that ended with atomic explosions over Japan, Milton Rothmar had been the author of an science fiction fanzine, *Milton's Mag*. He produced at least one issue in that second nuclear age, in October 1945. It contained this account of his reaction to the news about Hiroshima and Nagasaki:

> It was in the *Stars and Stripes* this morning, and even though I had been expecting it ever since hearing the first guarded stories from here

> and there concerning "Tennessee", the reality was hard to believe. The headline said "Atomic Bomb". To a person who has been raised on stories such as "The Final War," this was both a terror and a hope. Man could use this to destroy everything. He could also be scared so badly at its possibilities that impending wars would be staved off long enough for a world organization to get going properly. My own personal hope: that I can get home fast enough and get my Doctor's degree quickly enough so as to be able to get into the middle of the work that will be going on to slow down the atomic explosion and put it into a rocket motor. . . . When we stopped a few minutes at Rome, I heard somebody say on the radio the same remarks concerning the good and evil of atomic energy that I wrote above. It is obvious that many people are saying the same things and, in fact, we science fiction readers have been saying them for years.
>
> Goddam but it is thrilling to hear the words "atomic energy" used on the radio like they were talking about the latest model car. I feel like shouting to everybody "I told you so!"[21]

Rothmar's reaction is quite typical of Americans in those unsettled first few days of peacetime. He is optimistic that the long-promised fruits of liberated intra-atomic energy will soon be a reality. Surprised to hear the actual news, he nevertheless knew that a bomb was coming—not merely because the imperfect secrecy of the Manhattan Project had made its general nature an open secret toward the end of the war, but also because of his taste in literature. He recognizes the moral implications of a superweapon, and can be troubled by them. He holds out hope that one experience of these weapons would be exactly enough to frighten the world away from ever using them again—a common trope in the pulps' atomic war stories. And he is excited enough by the realization of one 40-year-old prediction for nuclear energy to once again hold out hope that others will follow.

In all these respects, Rothmar was emblematic of the emerging post-Hiroshima nuclear consciousness. He acquired his particular perspective by virtue of his immersion in a literary culture that had been over the implications of atomic weapons so many times as to make their invocation almost banal, but as this book has shown, nuclear culture had many manifestations, and very few Americans escaped some kind of engagement with it. Rothmar's gleeful "I told you so!" trumpeted the vindication of his fiction-fueled belief that he would live to see such a thing. Many of his fellow citizens had long ago stopped expecting atomic miracles to be extracted from radium (or uranium, as it happened). But both the optimists and the pessimists had made their predictions advisedly, with decades of shared experiences to guide them.

Rothmar was hardly alone in acknowledging the prescience of science fiction with respect to nuclear war. The *Saturday Evening Post* did so a few weeks into the second atomic age, with a reminiscence about the 1915 novel *The Man Who Rocked the Earth*.[22] "Fact is stranger than fission," its headline quipped. The *Saturday Review of Literature*, among others, found occasion in that year to reprint excerpts from the nuclear ur-apocalypse, H. G. Wells's *The World Set Free*. So did the *Fitchburg Sentinel*, in an editorial grappling with the very immediate question of how long radiation might linger after a bomb. The editorialist pointedly echoed Wells's description of a nuclear bombardier, who dropped his bombs with an expression like that of "an idiot child that has at last got hold of the matches." Three weeks after the bombs had been dropped on Japan, the ineradicable insanity that attached to the existence of city-destroying weapons was already a prominent theme in the public discourse on nuclear weapons, because it had been one all along.[23] *The World Set Free* was published just weeks before the start of the First World War, and earned Wells some uncomfortable praise for the prescience he showed in writing about a Europe-wide war culminating in aerial bombardments and weapons of mass destruction. Wells died in 1946, and his obituaries prominently featured his contribution to nuclear culture.

Nor did popularization and science journalism on the subject change much immediately after the war. Mushroom clouds provided another point of reference, and a grimly spectacular demonstration of the energy locked away in a few pounds of uranium, to go along with the shopworn examples of how far freight trains might be propelled. William Laurence of the *New York Times*, known as "Atomic Bill" after the War Department selected him as the designated journalist witness to the Trinity test and the Nagasaki bombing, was one of the most prominent architects of nuclear culture on either side of Hiroshima. The theory of a fission bomb was sufficiently well understood in advance that Laurence, who briefly held a monopoly on the popularization of up-to-the-minute nuclear physics, never really changed his approach to the subject, which he had been assiduously covering for years. He had written more than a hundred articles on radioactivity before the war for the *Times*, including one in 1940 that described in great detail the implications of German physicists' work on refining the fissile isotope uranium-235.[24] Compare the language he used on either side of the war. In 1940, uranium was "a veritable Prometheus bringing to man a new form of Olympic fire." In 1946, only the choice of metaphorical reference to antiquity had changed: because of uranium fission, mankind "stands on Pisgah in the desert, gazing at a land of promise. He has within reach the philosopher's stone and the elixir of life combined in one."[25]

Laurence had always been generally optimistic about the prospect of nuclear energies being harnessed for constructive purposes. By contrast, his colleague and supervisor Waldemar Kaempffert was deeply skeptical of the experimental reactors started up in the 1950s. He called the Shippingport plant an "expensive luxury," and warned that radioactive wastes would bring about a "slow, almost imperceptible deterioration of the human race," tantamount to a suicide of the species, if better methods of dealing with them were not developed.[26] An article on a nuclear technology he actually favored—a "feeble atomic battery" that used beta emissions from strontium-90 to generate a faint electrical current—pointedly noted that that substance was a dangerous "nuisance" left over from reactors.[27] But this was not the result of horror stories about fallout that Laurence had brought back from Japan or Bikini Atoll. Rather, it had been Kaempffert's considered opinion all along, one that he had shared at length with *Times* readers for years before the war. In 1939 he had described hypothetical nuclear reactors as akin to "overheated steam boilers" that would not only explode spectacularly, but salt the earth with radioactive dust. No thank you, Kaempffert wrote; for all the novelty of nuclear power, he would stick with a conventional coal fired power plant "and view with satisfaction what little smoke floats up from the stacks."[28]

For all the new perspectives that the stories coming out of Japan, Bikini, and the southwestern United States lent to Americans' understandings of nuclear energies in the postwar period, the first half century of encounters with irradiation remained convenient and meaningful points of reference. *Time* reported in 1958 on the "radium hangover" that people who had consumed Radithor in the 1920s were still experiencing. The occasion was an MIT study on the long-term effects of bodily radioactivity, which was increasingly weighing on the minds of those living in the fallout plume northeast of Nevada. The breath of those tested was still noticeably radioactive 30 years after the fact, and well above a safety standard for "maximum permissible body burden" set in 1941. Yet, to the reporter's evident surprise, the long-term survival prospects for Radithor consumers appeared to be good: of 160 volunteers, none had developed leukemia. *Time* suggested that perhaps those standards for safe levels of exposure had been overly conservative, and if so, perhaps some of the alarm about fallout was also unwarranted.[29] *Time* was hardly an apologist for nuclear testing; by the time this notice appeared, it had run nearly a hundred articles mentioning radioactive fallout, including one in the same issue reporting on how Geiger counters in Los Angeles were reaching alarming levels as a result of recent tests.[30] The juxtaposition of the old experience with the new, however, makes clear that the old symbols of nuclear energies were still current.

The bad habits of prewar nuclear culture proved hard to break, too. In 1962, the AMA received a letter from George F. Hammond, an 88-year-old man suffering from arthritis and hardening of the arteries. Hammond wanted to be put in touch with E. Stillman Bailey, whose ersatz radium tablets "Nuradium" and "Becquerelle" tablets were among the targets of the AMA's wrath in the mid-1920s. Hammond remembered them well enough to want to be put in touch with "Dr. Bailey," who had died in 1926, in the hopes of getting more of his product. He hastened to add that he knew how dangerous radium was, and that only proper doctors could safely administer it—this was the fruit of the long AMA campaign to bring radiotherapy fully within the walls of the medical establishment. But even though Hammond had taken the warning to heart, he still held out some hope for at least a mildly miraculous radium cure.[31]

Hammond received no reply, but it was clear to postwar AMA that they would not be able to consider the problem solved. Bad publicity had forced most Tricho machines from beauty shops by the early 1930s, but the AMA felt obliged to rehearse the horror stories of nonmedical irradiation in a 1947 *JAMA* article because cosmetic x-ray emitters were once again threatening the gullible and uninformed. This time it was the vanity and techno-optimism of men, rather than women, that was being targeted by the "X-Ray Razor." Worse, the second wave of commercial x-ray epilation devices seemed to be learning from the first: the authors noted with evident annoyance that the nature of the rays used was concealed in their advertisements by references to "a simple light treatment."[32]

Finally, x-rays and radioactivity continued to connote scientific modernity into the postwar period. At least with respect to nuclear energies, this need not have been the case: atomic bombs could have become the connotative property of Air Force pilots and the RAND Corporation. Most jobs at nuclear power plants do not require any particular scientific or technical background, which is why the inept and thoroughly unscientific Homer Simpson can plausibly hold down a job as a nuclear safety inspector on *The Simpsons*. (One episode reveals that Homer's lunch-pail colleagues do have masters' degrees in nuclear engineering, but that Homer was simply a local who got hired on the first day the plant opened. For many positions at nuclear power plants, that is entirely plausible.) But as Boyer and other postwar historians have made clear, the Second World War was immediately understood as the physicists' war, just as responsibility for the weapons of the First had been laid at the feet of the chemists. A Pulitzer Prizewinning editorial cartoon by David Low, published within weeks of the bombings, showed a generic lab-coated scientist bestriding the earth with papers marked "the atom" literally in his pocket. He offers the rest of humanity, depicted as an infant, a bauble labeled "life or death." "Baby play with nice ball?" reads the caption.[33] It was one of many such depictions.

* * *

Unlike many other "pop science" phenomena of the period, like relativity or aviation, the public interest in radiation and radioactivity was not exclusively the domain of a self-selected amateur elite. To be sure, its prominent manifestations in mass-market books about science, science fiction, and high school textbooks mostly reached the educated audiences that had cultivated a particular taste for science popularizations in early twentieth century America. Relativity, to take only the most prominent contemporary example, competed with radioactivity and x-rays for prominence in these media, while remaining little more than an enigmatic watchword for the unintelligibility of modern physics to audiences that otherwise took no special interest in science. The immediate and widespread commercialization of these new energies, as well as the unusual role they played in cementing orthodox medicine's claims to scientific authority made the emergent nuclear culture far more diverse than the parallel discourses on other scientific matters.

The role of clinical irradiation in expanding that culture is significant, but not the only factor worth considering. When, in the early twentieth century, one suffered a broken wrist, it was likely to result in a direct and essentially involuntary experience of an x-ray machine and its radiations. If that encounter sparked an interest in the phenomenon, opportunities abounded for voluntary and rhetorical explorations of the rays in the periodical press, or popularizing books, or science fiction. But many Americans' encounters with radiation and radioactivity were of a more ambiguous and casual nature that fit into neither category. In between are a rich variety of encounters that have attracted relatively little attention but which collectively formed the underlying fabric of the emergent nuclear culture of the age. Taken together, such encounters reveal an everyday dimension to the public experience of the phenomena. Postwar sensibilities regarding radiation and radioactivity have resulted in a temptation to underestimate the extent to which radiant energy *literally* permeated American lives, outside of the direct medical encounter. Shoe store fluoroscopy is only the most fondly remembered example, but the broad variety of casual, occupational, consumer-oriented, or otherwise miscellaneous encounters with radiant energy outside of a health-seeking context shows clearly that the popular understanding of those energies went far beyond what was gleaned from magazines or a trip to the dentist's office.

In many cases, these in-between encounters provided knowledge or connotative options that were absent from printed accounts or the constrained atmosphere of the clinic. Even the purple prose of the early newspaper accounts, in which the radiations were exalted as novelties (albeit powerful and significant ones), could have had none of the visceral impact of the wonder shows put on by hundreds of professional and amateur explorers of the new energies. Nor was the popular media equipped or willing to provide the level of detailed technical knowledge that public demonstrations did. And where doctors were often restrained by customs or professional strictures from advertising, other commercial x-rayers were not, permitting (literal) exposure to the technologies in freer environments than a deliberately sober and imposing examination room.

Such encounters also demonstrate the extent to which the new energies became a part of the cultural lexicon, in ways that other new scientific phenomena did not. Liquefied air was a novelty at the turn of the century whose popularity at scientific demonstrations briefly approached that of x-rays, but it inspired no advertising campaigns or product names. Aviation did, as well as a thousand books on the subject, but it remained beyond the direct physical experience of most Americans for the first part of the twentieth century. Radio was popular in every sense of the word, and an agent of major social transformations to boot, but its gradual evolution from antecedent technologies meant that it inspired more interest than awe. Radiation, however, was encountered on a regular basis even by those whose lives rarely intersected physically with it, or who never bothered to read about it. More than simply an icon of modernity, as I have styled it, radiation became a thing about which ignorance was not possible, even if desired.

* * *

Not only were Americans knowledgeable about radiation in that first atomic age, they had definite opinions about what it portended.

Consider a 1928 lecture Herman Muller gave to a local medical society at Baylor University. At the time, Muller was enjoying the sudden fame that had come with his discovery that x-rays could induce heritable (and occasionally beneficial) mutations in fruit flies. The talk was a disaster. His audience had hoped that he would paint a sunny picture of the bountiful crops that would result from seed irradiation, and perhaps to indulge in some speculation on the improvements that x-raying might work on the human germ plasm. Instead, Muller used the occasion to criticize the medical profession for its continual failure to ensure adequate radiation prophylaxis for physicians who used x-rays or radium. Worse, he pointedly rejected any suggestion that there might be some eugenic application of x-rays. This was so badly received by the audience that an invitation to give a similar speech to a radiological society—where even more offense might be taken—was revoked.[34]

These Texas physicians, most of whom would have operated x-ray machines themselves at some point in their practices, did not react badly because they were ignorant of the dangers of occupational exposure, or unwilling to acknowledge them. They reacted badly because they already had a bench-rule understanding of x-rays; they were used to thinking about them in terms of mundane practicality. What they wanted from Muller was a glimpse into the numinous. This was, after all, what they themselves gave their patients, who still gawked at the giant machines that generated the rays, and who still occasionally demanded to take home the plates of their own broken bones, even 30 years after the x-ray portraiture fad had peaked. They felt entitled, as so many other nonscientists had, to see their own perceptions of the rays flattered.

It was possible for the public to develop such strong and idiosyncratic perceptions because x-rays and radioactivity had been, from the start, construed as things to which scientists and doctors had no special claim. They were generated from complicated electrical machines that a doctor might have, or isolated in a chemistry laboratory, to be sure, but they were otherwise in the public domain from the start. Besides, as was perfectly obvious to anyone who read the papers, radiation and radioactivity were not entirely at home in the scientific establishment. They were disruptive; they broke laws and unbalanced equations. They were, as the amused commentary from newspaper editorialists had it, "naughty."

Given the emphasis that was put upon that naughtiness in much of the lay discussion about them, the goodwill that accrued to their scientific elaborators is counterintuitive. It can be understood as the combined effect of four dominant themes that were introduced into the collective discourse about the new energies by a variety of actors. First, simply, that the work undertaken by the Roentgens, Becquerels, and Edisons, and latterly by the Millikans and Joliot-Curies, was extraordinarily difficult. Second, that this skill was matched by a sort of moral superiority—the ruthless intellectual honesty or the dogged patience that permitted them to perceive the faint flickers of energies where none before them had. Accordingly, they were often portrayed retroactively as rebels or insurgents within a moribund scientific establishment. For precisely this reason, they were often credited with the democratization of the rays. The entrepreneurial network actually responsible for the broad accessibility of real and imagined encounters with radioactivity were happy to frame radium as Marie Curie's "gift to the world;" it served their interests quite well to promote the idea that scientists were modern-day Prometheuses bringing atomic fire for the benefit of humanity. Curie herself deplored individual acts of radium fraud, but she and her colleagues benefited from the association all the same.

Recurring Themes in Early American Nuclear Culture

This book has been structured around three phases in the public understanding of radiation and radioactivity: initial crazes beginning in 1896 and 1903 respectively, which were followed by a period in which experiential contact increasingly shaped Americans' largely ray-positive sentiments. Toward the end of the 1920s, that prevailing mood gave way to anxiety and fear of contamination or disease, as a result of the rays' stagnation as a medical miracle, the constant reiteration in the news media of radiation-related deaths, and the establishment of a more critical breed of science journalist. The tenuous network of actors who strove to inject "ray-talk" into the public discourse partially collapsed as a result, with the spa owners and nostrum-marketers who promoted the energies cutting their losses and ceding the field to AMA bulletins and FDA radio programs that demonized radiation.

It should be obvious that these are general guidelines, and not prescriptive boundaries. Many, many individuals tacked into the prevailing winds in any given age. There is no single "public understanding" of these energies. No typical roster of experiences with respect to these energies exists: there were too many different paths an individual might take past the various actors seeking to alter the public's perception of x-rays or radium. As chaotic as the discourse became, however, some patterns emerge when the first half century of nuclear culture is viewed from a distance.

One is the striking longevity of the discourse itself. For all the ray-talk that characterized the half century ending with Hiroshima, ray-fatigue is scarcely in evidence. Except during wars, when there was a measurable decline in newspaper stories dealing with the energies, the presence of energetic radiation and radioactivity in public discourse was qualitatively similar throughout the entire period under consideration—and quantitatively much greater, given the expansion of science journalism, popular books, and the science fiction press. No single reason explains the persistence of the laity's interest in these energies, although the fact that they were never regarded monolithically as good or bad, helpful or harmful, hopeful or foreboding, or natural or artificial surely played a role: things that are controversial, or at least unsettled, are less likely to cede the spotlight. Radio and the electric light were manifestations of the same physical phenomenon as x-rays, and relied on similar technologies (at least insofar as all of them involved passing electricity through evacuated tubes), and both penetrated more deeply and permanently into the fabric of everyday American life. To the extent that they were revolutionary technologies, however, that revolution was a swift and successful one: even though many American households had to wait for electrification or the ability to receive more than a few weak stations, the promises made for them at their introduction had largely been proved in principle (or dispelled by demonstration) within a short time. Progress with the rays, however, was in unpredictable fits and starts, beginning with the spectacular unexpectedness of their discovery.

That erratic nature—the persistent novelty and irreducible weirdness of these new energies—was one of several factors that proved particularly influential with respect to the general directions of early American nuclear culture. From the vantage point of a century or more, it is easy to ignore, or undervalue, the importance of the weirdness of their physical properties—both real and imagined—to the rays' endurance as a topic of intense public interest. The omniscience of an x-ray exposure, or the seemingly infinite emission of energy from pitchblende ore were not only fantastic or extraordinary, but essentially unheralded even by reference to mythology. At the very least, the insight made suddenly possible by the x-rays seemed like magic, if not something altogether more profound: discussions of the rays frequently found occasion to cite Matthew 10:26, "For there is nothing covered that shall not be revealed, and hid that shall not be known." Their promise as a treatment for skin complaints, including leprosy, suggested other Biblical references.

Science reportage in the early part of the twentieth century, particularly the first two decades, has been justifiably called sensationalist, inconsistent, and occasionally incomprehensible. That the press repeatedly exaggerated, conflated, or misstated the properties of x-rays or radioactive substances does not detract from the genuine surprise that laypersons felt over the kernel of truth that underlay those stories. The rays' central place in the traveling wonder shows of 1904, alongside liquefied air and stereopticon slides was a function of their newness; that they remained a staple of such demonstrations four decades later had more to do with the fact that their standing as the preeminent scientific oddities of the day had scarcely been challenged.

Their intrinsic oddness attracted attention to the rays in the first place, but they were kept in the spotlight by human agency. For one thing, they proved adaptable to money-making purposes. Financial interests motivated a diverse array of actors to become opinion-shapers on the subject of radiant energy. Roentgen had refused to seek any sort of patent on the x-ray-generating process; the Curies were similarly generous with their work on radium and their methods of extracting it. But altruism with respect to radiation ended there—and, of course, both Roentgen and the Curies profited handsomely in professional and public circles by those decisions. If the rays were remarkable for the degree to which they penetrated both Americans' bodies and minds, they could not have done so but for the extraordinary opportunities they presented so many different people and institutions. That such opportunities existed had much to do with the fact that their production and use quickly came within reach of nonscientists: instantaneously for x-rays, which could be produced by well-stocked high school science workshops by early 1896, by the middle of the first decade of the 1900s in the case of radium emanation at any number of hot springs resorts, and by the mid-1910s in the case of radium itself in the form of plausibly radioactive products. The cordon sanitaire that government and medical authorities tried to slip around them was porous: even in the 1940s nonmedical fluoroscopy services, radium-painted devices, and radium emanators were still commercially available. In the meantime, hundreds of businesses in radium devices alone had come and gone (the Denver city directories for the 1910s and 1920s are a testament to the ephemeral nature of firms with the word "radium" in their name), to say nothing of the local x-ray outfits, beauticians, osteopaths, photographers, mining speculators, salesmen, and even the occasional artist who found ways to incorporate the actual energies into their business.

That network included those whose interest in the rays was contingent more on public fascination with them than in their actual properties, too. Wonder showmen, science fiction authors, speechifying scientists, medical practitioners both pro- and anti-radiation, and especially newspaper science reporters and their editors were all acting out of self-interest in their commentary on the new energies. That their commentary was neither uniformly positive in its tone, nor accurate in its representations, is of little importance in assessing the magnitude of their effect in sustaining interest in radiation and radioactivity. This is evident from the partial collapse of the portion of the network of interested actors who derived benefits from the sale of radiation-related products in the late 1920s and 1930s. In the aftermath of the US Radium workers scandal and the death of Eben Byers and Marie Curie, ray-generating products and services became scarcer and more clinic-bound as a function of dwindling demand for a phenomenon whose connotations were trending negative. But negative attention is nevertheless attention, and the broad recasting of radium and x-rays as carcinogens and mutagens (as opposed to cancer cures, potency restorers, plant foods, and the like) was as attractive a subject for popularizers as the initial, largely positive periods of enthusiasm had been.

As noted in the previous chapter, even actors whose interests were diametrically opposed in other regards, like the medical establishment and anti-radiation sectarian healers, could find common cause in their promotion of a given ray-ideology. In the face of a public far too sanguine for their tastes about personal exposure to ionizing radiation, the question of whether the rays were *ever* medically appropriate was a small one, and their collective efforts were effective in adding a sour note to the stream of ray-talk. It was this discordant note (of which they were only the most prominent singers) in a predominantly positive and optimistic discourse about the energies that made possible the quick collapse of the faith that many Americans had invested in them. Without it, it is difficult to imagine even the formidable radiation-related disasters of the late 1920s and early 1930s gaining much traction.

Popular perception of radiation was fundamentally linked to its capacity to affect the human body. For all the interest that the omniscience of the x-ray or the potential mechanical application of radium's energy aroused, it was the criterion of physiological activity that ran most deeply through the laity's interest in these new energies.

The abundance of science fiction stories in which radium is used not as a fuel or a weapon but a biomedical cipher of some sort alone is strong evidence to this effect, reflecting clearly the inherently vitalist understanding of that substance. Sometimes, the new energies were presented in straightforward terms as a vital spark, or a philosopher's stone by other means—something fundamentally alive or inherent in the process of life. It was this strain of thought that was incubated and elaborated by the early proponents of radioactive springs and mild radium therapy, who invariably used language that treated radiation as a natural process. X-rays and ultraviolet rays were like concentrated sunlight; radium was the "magic mineral."[35] Native Americans, already closely identified with a sort of Edenic nature in the popular discourse, featured heavily in anecdotes conveying folk wisdom about the rays. From Arkansas to Colorado, the idea of a *pax aquatica* at local sacred waters was repeated. The merchants of Idaho Springs, Colorado, put words in the mouth of the apocryphal Indian chief that was the town's namesake, having him anachronistically proclaim that "happy [is] the rheumatic that takes a Radium bath and is benefited, but more happy is the one that takes a Radium bath every month and never has rheumatism."[36]

However, the connotative root of many other expressions of radiation's effect on the body was of strangeness—a liveliness that, while real, was somehow alien or unnatural, more akin to the electrochemical wizardry of *Frankenstein* than the divine spark. This was not always understood negatively; if a Finsen lamp produced "artificial sunlight," it might nevertheless do some good. But there was usually at least some ambiguity about the weird effects the rays could produce. A newspaper article from 1904 about the various ways that radium, x-rays and ultraviolet rays could be applied to the body framed the text with a quote from Jeremiah: "Can the Ethiopian change his skin, or the leopard his spots?" illustrated by images of an African man and a leopard, both purportedly bleached by the action of radium.[37] Here were things that could confound the wisdom of prophets: the article duly noted the challenge in finding a dose of rays that did less harm than good. It was that set of rhetorical tools—the inherent bizarreness of radiation's physical effect, which showcased its unpredictability and the ugly side of its potency—that were taken up in the late 1920s and 1930s as sentiment curdled, and radiation became understood more clearly as a carcinogen or mutagen than a panacea. The public was not so much horrified by the deaths of Byers, Curie, or factory workers as they were reminded that horror had always been an interpretive option.

In fact, there were always a variety of interpretive options available, which further enhanced nonscientists' interest in the rays. At every point, the predominant sensibility was contested, often vigorously, and that struggle between divergent ideas about how the energies should be understood served to keep aloft the level of attention paid to them. The actors with direct financial interests in the public perception of the novel energies were numerous, diverse, and collectively powerful. That they did not always pull in the same direction, and indeed that they were occasionally scarcely aware of one another's existence, is of relatively little importance. Ray-mania was lampooned in real time by exasperated magazine commentators. The rare patient burned by a radium treatment—or the far more common one who feared burning—could find any number of unorthodox medical practitioners ready to present alternatives in ways that both assuaged and culturally legitimized that fear. In the commercial realm, the ambiguous method by which radiation served to accomplish the ends manufacturers claimed for it permitted a host of distinctive technologies to arise, with adherents of each making a pointed and distinctive claim that helped to shape consumers' understandings. For example, bottled radioactive spring waters, emanator-treated water, radium-infused water, and x-irradiated water all had separate theories, stressing in their advertisements (respectively) the therapeutic values of the mineral content, the potency of fresh radium emanation, the necessity of a sizable dose, and the *absence* of residual radioactivity in their products. These were contradictory and occasionally contentious claims. Singly, such assertions might have convinced a few consumers of the value of self-administered radiation; collectively, they created a rhetorical space in which that was taken for granted and only the more specific claims were contested.

The plethora of attitudes toward and knowledge about radiation cannot be reduced to straightforward statements about "the public mind." Knowledge and interpretations varied, and occasionally clashed. That unanimity of opinion regarding nuclear emanations did not approach that of, say, aviation or antisepsis—or even phenomena that were contentious and contested, like vaccination or Taylorism—heightened the prominence of the rays themselves, and raised the stakes for the wide variety of agents with an interest in the disposition of those opinions.

Similarly, the public profile of the rays was also elevated by the dissonance their very existence caused within the scientific and medical establishments. Because knowledge about radiation and radioactivity was ubiquitous (if hardly uniform), and because the one common theme running through virtually all discussions of them was that they were of unusual significance, they became leading indicators of public perceptions of scientists. As I have noted throughout this book, the rays made celebrities of those who came in contact with them, and this was never more true than with their principal investigators in the laboratory: the Curies, Becquerel, Soddy, Rutherford, Hammer, Edison, Tesla, Millikan, and so forth. This is easily understood by virtue of the fact that their work on the nature of the new energies (or their work in developing its applications) put them at the center of, and therefore highly visible within, a physics establishment that was daily gaining authority and respect in American society. Yet in the usual popular characterization of the rays, they were unruly things whose mysterious nature was all the more remarkable for its destruction of the established naturalistic understanding of the world: they unbalanced chemical stability, threatened conservation of energy, forced new reckonings about the age of the earth and the sun, extended the spectrum of light, and muddied the waters as to its nature.

Conclusion

In April 2003, *National Geographic* ran in its back pages a forgotten photograph from the archives of the Westinghouse Electric Corporation—an x-ray image from 1941 showing the head of a bespectacled man shaving with an electric razor (See Figure 5.1).

The image is comical and fascinating. Westinghouse presumably hoped that the delightful picture would arrest the attention in an advertisement long enough for them to make their case for the razor.[38] At just about the same time, a division of General Electric (a leading manufacturer of x-ray equipment) was seeking to put a friendlier face on the rays themselves, with its informational pamphlet *The Story of X-Ray*, in which it noted that as a hobby, some radiologists took beautiful x-ray images of flowers. It also noted that the mutations produced by irradiated seeds were making for new and hardier varieties of plants (something gardeners would have known for some time, as that fact had been prominently folded into the advertisements for the seeds). Another contemporaneous pamphlet by Eastman Kodak, *X-Rays . . . and You*, addressed the fears that patients might have about undergoing medical irradiation.[39] It is striking that the same physical phenomenon was being used by large industrial concerns for diametrically opposed purposes—to provide "human interest" for one product on one hand, and to be "humanized" on the other—especially

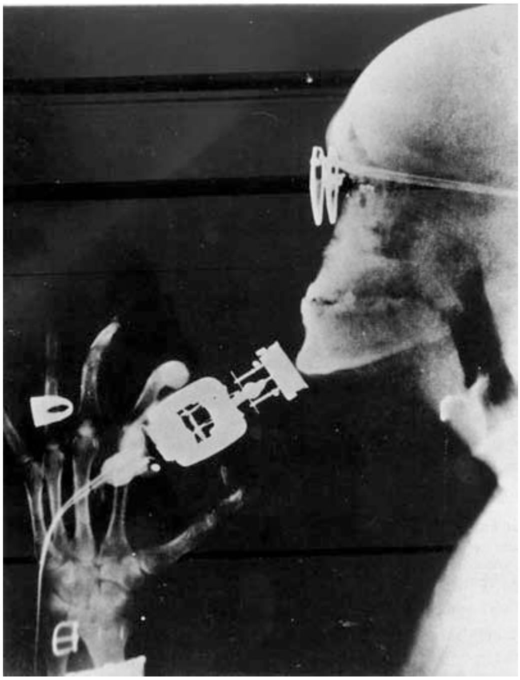

Figure 5.1 Westinghouse Electric Corporation promotional photograph, 1941. Reproduced by permission of CBS.

considering the fact that x-rays had been explained ad nauseam for nearly 50 years. Would the public not see in the razor advertisement a dangerous and unnecessary exposure to radiation? What could these pamphlets say that even an adolescent in the 1940s had not heard a dozen times before?

To understand the apparent contradictions, we must recognize that the discussion about x-rays, and all forms of radiation, never achieved coherence because of the multiplicity of motivations on the part of the actors who participated in it. We can identify the direction that the wind was blowing at any given moment in the history of early American nuclear culture, but the devil is in the details. Minority viewpoints were always present, and all perspectives were constantly being tested and augmented by interested parties. Westinghouse would have had reason to be satisfied with the general public sentiment about diagnostic x-ray machines in 1941, to the point that its admen pondered the idea of using it to sell less familiar technologies.

But General Electric would also have had legitimate reason to fear complacency about that general goodwill, given the volatility of opinion on the subject of radiation, and the sheer number and variety of actors who had sought to move that prevailing opinion in one direction or another.

Perhaps the most remarkable thing about radiation and radioactivity was that nearly half a century on from their discovery, it was still impossible to fully characterize public sentiment toward them, or say just what any given person might know about them. They had remained throughout impossible to adequately explain, impossible to restrict to intuitive or predictable behaviors, and thus impossible to fully ignore. No other marvels in an age of marvels retained their capacity to provoke commentary and controversy for so long.

In the process of "getting into the heads," to the extent possible, of nonscientists in their early encounters with these energies, I was surprised at the range of understandings they had, and the diversity of the channels through which they received their information. Perhaps this has caused me to adopt an incautious empathy for the people who maintained such nuanced and contradictory understandings of radiation and radioactivity, but I would like this book to serve as a caution against the assumption that lies deeply buried in many of those excellent works about the postwar period—namely, that the first few reports from Hiroshima and Nagasaki were for all practical purposes the chief and only formative moments of American nuclear culture.

The "second Atomic Age" was new territory, but hardly an entirely unfamiliar landscape for Americans with decades of accumulated experience in coping with radiation. Nor was it populated with unfamiliar actors: advertisers, poets, and scientists all figured heavily in the flowering of the postwar nuclear consciousness, too. Ultimately, the most important difference in American nuclear culture between the half century preceding Hiroshima and the decades that followed it was the difference between potential and actual. In 1930, radioisotopes *might* blow up a city, or power it; by 1960 they had done both. The spectacular unveiling of nuclear weapons forced the American people to make a new set of decisions about radiation, but they did so mindful of the half century they had already spent in an Atomic Age.

Notes

1 Introduction

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22. See Maria Rentetzi, *Trafficking Materials and Gendered Experimental Practices: Radium Research in Early Twentieth Century Vienna* (New York: Columbia University Press, 2007).
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2 Crazes

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2. "Through Solid Flesh," *Chicago Daily Tribune*, January 19, 1896, 38.

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10. Cf. "Bryan's Railroad Pass," *Los Angeles Times*, August 30, 1897, 4. Or, see, for example, "Examined," *Zion's Herald*, September 8, 1897, 567.
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22. "X-Ray Notes," *Public Opinion*, August 23, 1898, 241.

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24. Cf. *The Story of X-Ray*, promotional pamphlet, General Electric, undated. Bakken.
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33. "Marvelous Cures Made by Radium," *Chicago Tribune*, October 11, 1903.
34. "Radium Restores Sight," *New York Press*, January 23, 1904.
35. "Radium Garments," *Chicago Chronicle*, September 19, 1904.
36. "The Discoverers of Radium Can Detect False Diamonds by Its Use," *Syracuse Telegram*, February 25, 1904.
37. "Handful Would Destroy London," *Springfield* [Massachusetts] *Union*, November 29, 1903.
38. William Rittenhouse, "The Modern Philosopher's Stone," *Forward*, March 26, 1904; "Radium in Findlay," *Findlay* [Ohio] *Courier*, February 16, 1904; "Worth Millions a Pound," *Baltimore Sun*, December 16, 1903; "Cheap Thorium Rivals Radium," *New York Herald*, January 23, 1904.
39. "Want Radium Put on the Free List," *New York City American*, September 14, 1904.
40. "Bogus Radium Claims," *Washington Post*, May 8, 1904.

41. See especially Luis Campos, "The Birth of Living Radium," *Representations* 97 (Winter 2007): 1–27. Campos considers the way in which writers rendered radium rhetorically alive, and concluded that the intensity of the vitalist language at the peak of the radium craze was such that it actually reciprocally informed how physicists and biologists understood the connections between their disciplines.
42. C. W. Saleeby, "Radium and Life," *Harper's Weekly*, July 1906, 226.
43. Robert Kennedy Duncan, "Radio-activity," *Harper's Monthly Magazine,* August 1902, 366.
44. "Can Life Be Produced by Radium?," *The Independent*, September 7, 1905, 556.
45. "Man Competing with Radium," *Literary Digest* 44, February 3, 1912, 209.
46. "Sleeping Plants Wakened by Radium," *Literary Digest* 48, April 11, 1914, 817–818. The association between plant growth and radium is older, though; see "Radium and Vegetation," *Leavenworth* [Kansas] *Times*, December 6, 1903.
47. Cf. Spencer Weart, *Nuclear Fear: A History of Images* (Cambridge, MA: Harvard University Press, 1988), 37.
48. "Radium: A Little Philosophy," *Richmond* [Virginia] *News-Leader*, April 2, 1904.
49. "Seance of X Ray Gosts [*sic*] of Paris: Wonderful and Startling Display—Thrilling Story Related in the Journal des Debats," *Chicago Daily Tribune*, March 27, 1897, 14.
50. James Hyslop, "Psychical Research on New Lines," *New York Times Sunday Magazine*, June 9, 1907, 7.
51. Garrett P. Serviss, partial newspaper clipping, undated and without headline (circa 1903). Hammer papers.
52. Representative accounts of such trials in the popular press include "'Visions' Seek Box Secret: Mediums and Latest Rays of Science Will Attempt to Penetrate Mystery of Southcott Chest," *Los Angeles Times*, May 2, 1927, 1; Dickinson S. Miller, "Statements of Investigators: No Evidence of Supernormal Powers, But Much Evidence of Trickery," *New York Times*, May 12, 1910, 2. Any number of excellent accounts exist of the trials of self-proclaimed mediums by scientists. See William Crookes, *Crookes and the Spirit World*, K. M. Goldney and M. R. Barrington, eds. (New York: Taplinger, 1972); Richard John Noakes, "'Cranks and Visionaries': Science, Spiritualism, and Transgression in Victorian Britain" (unpublished dissertation, University of Cambridge, 1998); R. G. Medhurst and K. M. Goldney, "William Crookes and the Physical Phenomena of Mediumship," *Proceedings of the Society for Psychical Research* 54 (1964), 25–157.
53. Catherine Caufield, *Multiple Exposures: Chronicles of the Radiation Age* (New York: Harper & Row, 1989), 8.

54. Cf. Martin Kemp, *Visualizations: The Nature Book of Art and Science* (Berkeley: University of California Press, 2001), 75.
55. "Marietta," *Daily Leader,* April 7, 1896.
56. Frederick J. Harrison, "Advance in Photography during 1896," *The Cosmopolitan: A Monthly Illustrated Magazine* 22, no. 3, January 1897, 341.
57. "New Scientific Verbs Wanted," *New York Times*, January 24, 1904, 6.
58. "X-Rays in Opera Glasses," *Electrical Engineer* 21, no. 408, February 26, 1896, 216.
59. "Roentgen Rays," *Alton* [Illinois] *Evening Telegraph*, February 25, 1896.
60. "The Roentgen Ray," *New York Times*, February 7, 1896, 4.
61. Untitled editorial, *Chicago Daily Tribune*, March 6, 1896, 6.
62. "The Roentgen Rays," *Journal of the American Medical Association* 36, (February 15, 1896): 336.
63. W. Fuchs, "Historical Notes on X-Ray Plates and Films," in *Classic Descriptions in Diagnostic Roentgenology*, André J. Bruwer, ed. (Springfield, IL: Charles C. Thomas, 1964), 97.
64. Ronald L. Eisenberg, *Radiology: An Illustrated History* (St. Louis: Mosby Year Book, 1992), 59.
65. Ibid., 58–60. The earliest American professional societies for physician-radiologists showed great sensitivity to that point. The constitution of the Roentgen Society of the United States included a provision that "no person shall be received as a delegate nor allowed to sit as a permanent member, nor as a member by invitation, who is known as a 'quack,' or under sentence of expulsion or suspension from any scientific or medical society." "Constitution of the Roentgen Society of the United States," *The American X-Ray Journal* 6, no. 3 (March 1900): 9.
66. Judd Aspinwall, *Practical Points in the Use of X-Ray and High-Frequency Currents* (New York: Rebman, 1909), v.
67. Fred O'Hara, "X-Radiance and the Lagging Doctor," *American X-Ray Journal* 2, no. 5 (1898).
68. Their ads ran repeatedly in St. Louis and Pittsburgh newspapers during 1903. See, for example, *The St. Louis Republic*, February 11, 1903, 2;
69. David Rhees, "A New Voice for Science: Science Service under Edwin E. Slosson, 1921–29" (MA thesis, University of North Carolina-Chapel Hill, 1979), 3.
70. This is admirably expanded upon in Paul Starr, *The Social Transformation of American Medicine* (New York: Basic Books, 1982), 19.
71. On the centrality of practical applications, see Oscar Handlin, "Science and Technology in Popular Culture," in *Science and Culture: A Study of Cohesive and Disjunctive Forces*, Gerald Holton, ed. (Boston: Houghton Mifflin, 1965), 190.

72. Henry Adams, *The Education of Henry Adams: An Autobiography* (Boston: Houghton and Mifflin, 1918), 381.
73. Ibid., 452.
74. William A. Dunning, "Henry Adams on Things in General," *Political Science Quarterly* 34, no. 2 (June 1919): 310.
75. Adams, *Education of Henry Adams,* 381.
76. "Still Another Radium Puzzle," *Suggestion*, April 1904.
77. William Rittenhouse, "The Modern Philosopher's Stone."
78. "A Modern Marvel," *Hawkeye* [Burlington, Iowa], December 6, 1903.
79. George Ehrhardt, "Descendants of Prometheus: Popular Science Writing in the United States, 1915–1948," (PhD diss., Duke University, 1993), 18.
80. "Radium Sets at Naught Science," *Schenectady Gazette*, January 27, 1904.
81. Max Nordau, "Superstitions of Radium: New Material Declared Not to Be Revolutionary," *Los Angeles Times*, March 20, 1904, C9.
82. "Radium Keeps the Earth Hot: English Scientist Attacks Molten Mass Theory," *Chicago Tribune*, May 21, 1904, 2.
83. "Laugh at Prof. Pratt: Eminent Scientists and Physicians Ridicule His Claims," *Chicago Tribune*, April 20, 1896, 2.
84. "Radium Photographs Reveal Strange Shadow Shapes," *Washington Times Magazine*, March 3, 1907.
85. "The Revolution in Physics Wrought by Ernest Rutherford," *Current Literature* 49 (September 1910): 281.
86. Cleveland Moffett, "The Sense and the Nonsense about Radium," *Success* 7, April 1904. Reprinted in *Current Literature* 36, June 1904, 649.
87. "Edison Won't Seek Radium," *New York Times*, February 20, 1914, 18.
88. "Science on the Road to Revolutionize All Existence," *New York Times Sunday Magazine,* September 28, 1913, 6.
89. Lawrence Badash, "Radium, Radioactivity, and the Popularity of Scientific Discovery," *Proceedings of the American Philosophical Society* 122, no. 3 (June 1978): 145–154.
90. The singular "substance" is not an oversight; polonium was almost never mentioned, even in passing, and in many images of her accompanying such accounts, she was literally illuminated by a beaker or test tube of radium, popularly assumed to glow in any form.
91. "Mme. Curie Fought Poverty before Success Came," *New York American*, December 27, 1903.
92. Cf. "Our Lady of Radium," *Herald-Transcript* [Peoria, IL], May 10, 1904. See chapter 3 for mention of the radium-illuminated religious iconography that went by a similar name.
93. "Woman Discovered Radium," *Marysville* [Ohio] *Evening Tribune*, September 24, 1910, 105.

94. "Lights All Askew in the Heavens: Men of Science More or Less Agog over Results of Eclipse Observations," *New York Times*, November 10, 1919, 17.
95. "Fluoroscope a Success," *New York Times*, May 12, 1896, 3.
96. See, for example, "Miss Roosevelt 'Loses Heart,'; X-Ray Tests at World's Fair Result in Speculation, as to Whether Finder is St. Louisan," *Chicago Daily Tribune*, June 1, 1904, 1.
97. Cf. Carolyn Thomas de la Peña, *The Body Electric: How Strange Machines Built the Modern American* (New York: New York University Press), 189.
98. Cf. Campos, "Birth of Living Radium," 13.
99. Fred Nadis, *Wonder Shows: Performing Science, Magic, and Religion in America* (New Brunswick, NJ: Rutgers University Press), 15.
100. Edwin Freeman, set of original X-ray photographs. Bakken. Artifacts collection.
101. "Radiant Matter," *Cedar Rapids Evening Gazette*, May 11, 1904.
102. "J. R. Scupham Gives Lecture," *Oakland Tribune*, January 20, 1904, 10.
103. Henry Tizard, "Lord Rutherford," *Notes and Records of the Royal Society* 4 (1966): 105–106.
104. See, for example, "J. R. Scupham Gives Lecture," *Oakland Tribune*, 10.
105. de la Peña, *The Body Electric*, 177.
106. William Hammer, untitled memorandum, June 5, 1926. Hammer. Box 2:6. Hammer became engaged in patent disputes and priority claims with several other people who claimed to have first formulated radio-luminescent paint, and on several occasions drafted documents like this listing in great detail the steps he had taken.
107. Letter, Henry Noel Potter to William Hammer, July 15, 1903. Hammer. Box 2:8.
108. Letter, William Hammer to Henry Noel Porter, July 20, 1903. Hammer. Box 10:1. Regrettably, these letters seem to be the only ones that Hammer deemed unfit for inclusion in his personal papers.
109. "Radium as a Substitute for Gas, Electricity, and as a Positive Cure for Every Disease," undated news clipping, Hammer Papers.
110. Letter, James Beck to William Hammer, October 29, 1903. Hammer. Box 2:9.
111. Hammer wrote the articles "Radioactivity" and "Radium" for the *Encyclopedia Americana*, for which he was paid $45 plus a set of the encyclopedia. Letter, George Kines to William Hammer, February 19, 1904. Hammer. Box 3, Folder 1. The Standard Chemical Company of Pittsburgh, the first large-scale radium refining operation in the United States, paid him $300 as a consultant in 1913. William Hammer to Joseph Flannery, February 6, 1913. Hammer. Box 3:10.
112. Letter, William Hammer to Calvin Rice, September 19, 1903. Hammer. Box 10.

113. Letter, Dayton C. Miller, (Case School of Applied Science, Physical Laboratory) to William Hammer, November 5, 1903. Hammer. Box 2:9.
114. Letter, Charles D. Raines (Business Mgr., *American Monthly Review of Reviews*) to William Hammer, September 28, 1903. Hammer. Box 8:2.
115. Letter, William Hammer to Pierre Curie, September 29, 1903. Hammer. Box 10.
116. Letter, William Hammer to Janeway, October 15, 1903. Hammer. Box 10.
117. Letter, William Hammer to W. H. Dillingham, October 6, 1903. Hammer. Box 10.
118. Letter, H. Legrand to William Hammer, May 5, 1906. Hammer. Box 3:3.
119. Edward Trevert, *Something about the X-Rays for Everyone* (Lynn, MA: Bubier Publishing, 1896), 29.
120. See, for example, Raymond Phineas Stearns, *Science in the British Colonies of North America* (Urbana, IL: University of Illinois Press, 1970); Brooke Hindle, *The Pursuit of Science in Revolutionary America, 1735–1789* (Chapel Hill: University of North Carolina Press, 1956); Philip J. Pauly, *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton: Princeton University Press, 2002); Hugh Richard Slotten, "The Dilemmas of Science in the United States: Alexander Dallas Bache and the U.S. Coast Survey," in *The Scientific Enterprise in America: Readings from Isis*, Ronald L. Numbers and Charles E. Rosenberg, eds. (Chicago: University of Chicago Press, 1996), 37–60.
121. For the appeal of experientially oriented treatises on scientific subjects for amateurs, see Rebecca Kinraide, "The Society for the Diffusion of Useful Knowledge and the Democritization of Learning in Early Nineteenth-Century Britain" (PhD diss., University of Wisconsin-Madison, 2006).
122. William H. Meadowcroft, *The A B C of the X Rays* (New York: American Technical Book Company, 1896), 7.
123. R. J. Strutt [Baron Rayleigh], *The Becquerel Rays and the Properties of Radium*, 2nd ed. (London: Edward Arnold, 1906), 194–204.
124. Charles Raffety, *An Introduction to the Science of Radio-Activity* (New York: Longmans Green, 1909), 187–196.
125. They include "The Energy of Radium," *Harper's Monthly* 120, December 1909, 52–59; "Transmutation: The Vital Problem of the Future," *Scientia* 11 (1912): 186–202; "Science on the Road to Revolutionize All Existence," *New York Times Magazine*, September 28, 1913, 6; and *The Interpretation of the Atom* (London: John Murray, 1932).
126. Richard E. Sclove, "From Alchemy to Atomic War: Frederick Soddy's 'Technology Assessment' of Atomic Energy, 1900–1915,"

Science, Technology, & Human Values 14, no. 2 (Spring 1989): 163. *The World Set Free* itself was quoted at length at the opening of the chapters dealing with radioactivity in the popular work by James Kendall, *At Home Among the Atoms: A First Volume of Candid Chemistry* (New York: Century, 1929), 204, 221, 238.

127. Frederick Soddy, *The Interpretation of Radium, Being the Substance of Six Free Popular Experimental Lectures Delivered at the University of Glasgow, 1908* (London: John Murray, 1909), 244–245.
128. "The Interpretation of Radium, by Frederick Soddy," *The New York Times Book Review*, July 10, 1909, 431.
129. On science in advertising, see Pamela Walker Laird, *Advertising Progress: American Business and the Rise of Consumer Marketing* (Baltimore: Johns Hopkins University Press, 1998); Vincent Vinikas, *Soft Soap, Hard Sell: American Hygiene in an Age of Advertisement* (Ames: Iowa State University Press, 1992); James Norris, *Advertising and the Transformation of American Society, 1865–1920* (New York: Greenwood, 1990); Daniel Delis Hill, *Advertising to the American Woman, 1900–1999* (Columbus: Ohio State University Press, 2002); Nancy Tomes, *The Gospel of Germs: Men, Women, and the Microbe in American Life* (Cambridge: Harvard University Press, 1998).
130. Curtis Lighting [advertisement], undated (circa 1920). Hagley.
131. Advertising pamphlet, Crandall Cutlery Company of Bradford, PA, "Radium Electric Finish, Don't Tarnish," circa 1910. Hagley.
132. Edward Gerson, "X-Ray Mania: The X Ray in Advertising, Circa 1895," http://radiographics.rsnajnls.org/cgi/content/full/24/2/544. Accessed December 10, 2011.
133. X-Ray Raisin Seeder [advertising handbill]. Hagley.
134. Hood's Sarsaparilla [advertisement], *New York Evangelist*, April 30, 1896.
135. Ayer's Sarsaparilla [advertisement], *Chicago Tribune*, May 24, 1896. Emphasis in original.
136. Cf. Paul Frame, "Atomic Brand Names," http://www.orau.org/PTP/collection/brandnames/brandnames.htm. Accessed September 1, 2011. Dr. Frame also permitted me to examine some of these artifacts directly at the Health Physics Historical Instrumentation Collection of the Oak Ridge Associated Universities.
137. Edward Gerson, "X-Ray Mania: The X Ray in Advertising, Circa 1895."
138. "Science to His Aid: He Wanted to Win Maria with 'X' Rays," *Los Angeles Times*, March 22, 1897, 8.
139. "Radium Roulette a New York Rage," *New York Evening Journal*, July 30, 1904.
140. L. H. Harris, "Uncle Jimmie and the 'X-Ray Doctor,'" *The Independent* 55 (December 10, 1903), 2907–2909.
141. Garrett P. Serviss, "Edison's Conquest of Mars," in *Sources of Science Fiction*, George Locke, ed. (London: Routledge, 1998), 3.

142. Untitled editorial item, *Los Angeles Times*, February 29, 1904, 6.
143. See, for example, "All Glitter Like Radium: Fakers Now Trying to Float Worthless Mines," *Los Angeles Times*, February 6, 1904, 10. "Now that the world is radium-mad it is an easy matter for unscrupulous persons to find dupes who can readily be made to believe that an ore . . . is radium-bearing and that fortune awaits him who takes the bait."
144. "Radium in Connecticut," *New Haven Register*, November 29, 1903. The article describes a detection process that would identify the ionization of air by radon dissolved in groundwater. Although it was not really understood in 1903, when the heyday of the radioactive spa was just getting underway, most water that passes through a sufficient quantity of rock contains a detectable quantity of radon, regardless of any particular concentration of uranium decay-chain radioisotopes.
145. "Who Wants a Radium Mine?," *New York Press*, May 8, 1904. "Radium in a Quebec Mine," *New York Evening Journal*, May 9, 1904.
146. "Rarest Radium Discovered in Wyoming," *Denver Post*, January 17, 1904. "Radium Mine Found: Carnotite Holds the Rare Element—An Important Discovery," *Indianapolis Journal*, December 27, 1903. "Radium in Colorado," *New York Tribune*, February 7, 1904. "Oklahoma Hills Conceal Radium," *Washington* [D.C.] *Times*, February 15, 1904. "Radium in the Wichitas?," *Kansas City Times*, February 16, 1904.
147. "Cheap Thorium Rivals Radium," *New York Herald*. Thorium was occasionally referred to as "Tho-Radium" by its vendors and the press, the better to underscore the point that it shared radium's property of radioactivity.
148. Arthur Brunel Chatwood, *The New Photography* (London: Downey, 1896), 19.
149. Cf. Percy Brown, *American Martyrs to Science through the Roentgen Rays* (Springfield, IL: Charles C. Thomas, 1936), 18–19.
150. "Her Latest Photograph," *New York Times,* May 29, 1898, 14.
151. Advertisement, *Life,* December 23, 1897, 794.
152. Advertisement, *The Great Round World and What Is Going on in It* 1, no. 21 (April 1, 1897), back matter.
153. Charles H. McCollum, *Pills and Proverbs* (Boston: Meador, 1941), 103.
154. Hospitals also quickly adopted x-ray technology, usually by clearing out space in the basement for an examining room and developing facilities. For the establishment of radiology departments in hospitals see Phillip C. Goodman, "The X-Ray Enters the Hospital," *American Journal of Roentgenology* 165 (1995): 1046–1050.
155. Judd Aspinwall, *Practical Points*, v.

156. 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: W. R. Jenkins, 1902), 26.
157. F. S. O'Hara, "Looking Backward," *Radiography & Clinical Photography* 8 (May–June 1932), 9.
158. Ernest Smith, *The Making of a Surgeon* (New York: Random House, 1942), 279.
159. R. M. Burlingame, advertisement, *Hendricks* [Minnesota] *Pioneer*, January 23, 1902, 5.
160. F. S. Kolle, "X or Roentgen Ray Results in Amaurosis," *American X-Ray Journal* 2 (1898): 149. The idea that the blind could be made to see by both x-rays and radium was indeed one of the more commonly voiced speculations in the newspapers, probably because each was rhetorically associated with light.
161. Eli Friedman, *Doctor Eli* (Cambridge, MA: Microglyphics, 1972), 52.
162. M. H. Richardson, *Boston Medical and Surgical Journal*, September 3, 1896. Cf. Ruth Brecher and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: Williams and Wilkins, 1969), 66. X-rays can, in fact, have an analgesic effect to the extent that they kill nervous tissue.
163. "New X-Ray Robs Tube of Danger," *New York Times*, April 12, 1908, 1. "X-Ray Record for Ten Years," *Los Angeles Times*, August 24, 1908, 13.
164. Arthur Dunn, "Roentgenology from the Standpoint of the Internist," *Journal of Roentgenology* 2 (1919): 297.
165. O'Hara, "Looking Backward," 6. The "blister" would have been a radiation-induced erythema (an x-ray burn, in other words) and would have appeared after the actual treatment.
166. This is amply demonstrated in period cartoons and light fiction. Lightning bolts striking objects was a common theme in the iconography of x-ray manufacturers, too: the American College of Radiology's archives contain a collection of logos and trademarks for such companies, and electricity is the dominant theme in prewar period, only yielding to "atomic" imagery in the postwar period. ACR. Box 534.
167. Harold Swanberg, "X-Ray Electrocution," *The Radiological Review and Chicago Medical Recorder* 49 (1927): 440. This article claims "a noticeable increase of electrical deaths due to X-ray apparatus,—if we are to believe newspaper reports," but gives no statistics. One example is reported in "X-Ray Shock Kills Patient Ready for Tooth Examination," *Pittsburgh Press*, November 12, 1920, 28. One author called the relatively small number of serious electrical injuries "a matter of good fortune, as opportunities for contact with dangerous conductors have been extremely general." J. S. Shearer, "Electrical Dangers in X-Ray Laboratories," *American Journal of*

Roentgenology 7 (1920): 432. See also William F. Hemler, "High Tension Electric Shocks in Roentgenologic Practice," *American Journal of Roentgenology* 9 (1920): 365–370.

168. For example, Roland Hammond, "Fracture Work," *American Quarterly of Roentgenology* 4 (1911): 12. In the transcribed discussion following this article, Dr. Arthur Holding refers to having witnessed "several instances where the spark has caused serious damage" by igniting an ether fire.
169. Leo G. Rigler, "A Half Century of Radiology: The Herbert Lecture," March 1973. ACR. Box 531.
170. Willyoung X-Ray Apparatus and Accessories, catalogue (December 1896, no. 185), via James G. Biddle, Philadephia agent. Emphasis in original.
171. Lewis G. Cole, "Speed Mania," *American Quarterly of Roentgenology* 2 (1910): 129–135.
172. John T. Pitkin, "Dangers of the X-Ray Operator," *Archives of Electrology and Radiology* 4 (1904): 11.
173. Cf. Goodman, "The X-Ray Enters the Hospital," 1049–1050.
174. The improvisatory use of a chair, a footstool, and a fairly athletic patient cantilevered over them in order to achieve the proper angle and distance for a pelvic irradiation is illustrated in Guy Pallardy, Marie-José Pallardy, and Auguste Wackenheim, *Histoire Illustrée de la Radiologie* (Paris: Editions Roger Dacosta, 1989), 477.
175. See, for example, the illustration in Richard F. Mould, *A Century of X-Rays and Radioactivity in Medicine: With Emphasis on Photographic Records of the Early Years* (London: Institute of Physics Publishing, 1993), 34.
176. For reference to hour-long diagnostic exposure times, see Michael Pupin, *From Immigrant to Inventor* (New York: Scribner's Sons, 1923), 307.
177. J. M. Martin, *Practical Electro-therapeutics and X-ray Therapy with Chapters on Phototherapy, X-ray in Eye Surgery, X-ray in Dentistry, and Medico-legal Aspect of the X-ray* (St. Louis: C. V. Mosby, 1912), 216. Martin took a belt-and-suspenders approach to controlling for patient anxiety: "When the patient is unfamiliar with the working of the machine, he should be made to understand that there will be some noise, but that the flashes can in no way hurt him in the least. Small children, if nervous and easily frightened, should be chloroformed. . . . With nervous patients it is often necessary, when skiagraphing a limb, to strap it to the table with sand bags."
178. Percy Brown, "The Desirability of Complete Immobilization in Roentgenizations of the Head," *American Journal of Roentgenology* 2 (1915): 680–683.
179. William James Morton, "The X Ray and Its Application in Dentistry," *The Dental Cosmos* 38 (1896): 478–486.
180. Leo J. Hennie to H. M. Berg, June 19, 1964. ACR. Box 531.

181. Albert Franklin Tyler, *Roentgenotherapy* (St. Louis: Mosby, 1918), 40.
182. Buck X-Ograph Company, catalog, 1937. ACR. Box 658.
183. "Editorials," *American Journal of Roentgenology* 3 (1916): 335–336.
184. A. Howard Pirie, "Preparation of Barium Sulphate for the Opaque Meal," *American Journal of Roentgenology* 1 (1914): 220.
185. Henry Hulst, "Zirconium Oxide, A New Substitute for Bismuth Compounds in Roentgenology," *American Quarterly of Roentgenology* 2 (1910): 199.
186. Henry Pleasants, *A Doctor in the House* (Philadelphia: Lippincott, 1947), 186.
187. Richard F. Mould, *A History of X-Rays and Radium with a Chapter on Radiation Units, 1895–1937* (Sutton: IPC, 1980), 6.
188. Cf. Brecher and Brecher, *The Rays*, 60.
189. Albert Soiland, "A Plea for Combining the X-Rays with Surgery in Mammary Carcinomata," *Southern California Practitioner* 19 (1904): 261–264.
190. H. W. Dachtler, "Preliminary Report on Post Operative Roentgen Irradiation Following the Radical Operation for Carcinoma of the Uterus," *American Quarterly of Roentgenology* 2 (1909): 42–47.
191. Arthur C. Christie, *A Manual of X-Ray Technic* (Philadelphia: J. B. Lippincott, 1913), 95.
192. Pitkin, "Dangers of the X-Ray Operator," 4.
193. Anderson, Norden & Co, photocopied pamphlet, 1907. ACR. Box 655.
194. Emil H. Grubbe, "Results and Technique in Treating Epithelioma with X-Rays," *Transactions of the American Roentgen Ray Society, Third Annual Meeting* (December 10–11, 1902), 83.
195. Wilbur S. Hamilton, "Radio-Therapy," *The Electro-Therapeutist* 11 (1907): 111–118. Emphasis added.
196. Weston A. Price, "The Treatment of Pyorrhea Alveolaris with the X-Rays," *Archives of Electrology and Radiology* 4 (1904): 78–79. "It is very significant that, though the lady had to come a long distance and was not able to get on and off the cars without considerable difficulty and danger, she would telephone between appointments for permission to come, giving as her reason that her gums felt so much better for a day or two after treatments."
197. Robert Abbe, "Radium and Radioactivity," *Yale Medical Journal* 11 (June 1904): 1.
198. "Fashionable Now to Be Scientific," *New York Herald* (December 13, 1903). Hammer. Box 59:1.
199. Ambrose Bierce, *The Devil's Dictionary* (New York: Neale Publishing, 1911).
200. See, for example, the advertisement in the *San Francisco Call*, March 12, 1905, 30. Chamley also had a clinic in St. Louis simultaneously.
201. Albert Soiland, a prominent first-generation radiologist, later fumed about the damage done over the years by the fact that this "notorious

cancer quack" had settled on one of the few legitimate and demonstrable applications of x-radiation. Albert Soiland, "The Cancer Problem of the Female Breast. An Analysis Based upon 25 Years' Personal Experience with Radiation Therapy," *Acta Radiologica* 4, no. 5 (1925), 391–396.

202. H. M. Berg, "A History of Radiology in North Dakota," (unpub. ms, undated [post-1955]). ACR. Box 531.
203. For example, Leonard A. Levy and Herbert G. Willis, *Radium and Other Radio-Active Elements: A Popular Account Treated Experimentally* (London: Percival, Marshal, 1904).
204. Letter, Leopold Biddle to George F. Kunz, July 5, 1904. CSWR (Center for Southwest Research).

3 Commodification and Democratization

1. "Increasing Gravity of the World's Radium Crisis," *Current Opinion* 56, March 1914, 199–200.
2. "Save the Radium," *Current Literature* 65, June 26, 1920, 114.
3. Letter of Howard A. Kelly, *New York Times*, January 25, 1914, 10.
4. "More Radium Is Crying Need Now, Says Dr. Kelly," *New York World*, January 20, 1914.
5. "Pleads for Radium," *Washington Post*, January 7, 1914.
6. "Fight for Radium Control Is Opened," *New York Sun*, January 20, 1914.
7. "To Treat Cancer in Early Stages," *Spokane Daily Chronicle*, February 6, 1914.
8. "Professional Ethics," *New York World*, January 12, 1914.
9. "Radium Publicity," *New York Press*, January 15, 1914.
10. "Radium and Reactionaries," *Wilmington Star*, January 18, 1914.
11. "No Publicity Charge against Dr. Kelly," *New York Press*, January 13, 1914.
12. For example, "Miss Quayle a Patient," *Baltimore Sun*, January 17, 1914.
13. "Dr. Kelly to Confer with Congressmen," *Baltimore Sun*, January 14, 1914.
14. Ernest Daland, "Radium Therapy—Use and Abuse," *New England Journal of Medicine* 198, no. 19 (1928): 1005.
15. See, for example, the (unsuccessful) attempt in Philadelphia in 1933: "Radium Thieves Dicker for Return," *Evening Bulletin* [Philadelphia], August 28, 1933.
16. Roger Macklis, "Radithor and the Era of Mild Radium Therapy," *JAMA* 264, no. 5 (August 1, 1990): 614–618.
17. See, for example, "Radium Stolen," *Tacoma Times*, December 13, 1931, 1.
18. "Hospital Drama," *Philadelphia Record*, August 8, 1938.

19. Robert B. Taft, *Radium Lost and Found* (Charleston, SC: Jno. J. Furlong and Son, 1938), 40.
20. "Radium Detective Uses Electric Bloodhound," *Popular Science*, October 1940, 100–101. Cf. "How to Find Lost Radium," *The Literary Digest*, November 6, 1920, 29.
21. M. Donald Blaufox, "Radioactive Artifacts: Historical Sources of Modern Radium Contamination," *Seminars in Nuclear Medicine* 18, no. 1 (January 1988): 46–64.
22. Science Service, untitled MS, archivally dated January 24, 1938. SIA. Accession 90–105, Box 62.
23. Ingersoll Radiolite Watches [advertisement], undated. Hammer.
24. Pioneer Corporation, Magic Eradium Luminous Crucifix [advertising pamphlet], undated. Hammer. Box 66:3.
25. Eastern Luminous Indicator Company [photocopy of advertisement], circa 1920. Hagley. Energy released by radium gradually breaks down the molecules of the fluorescing agent into non-fluorescing compounds. Weaker solutions of radium glowed imperceptibly less brightly, but lasted much longer.
26. Blaufox, "Radioactive Artifacts," 46–64; "Seeing Things at Night," *Literary Digest*, February 5, 1921, 24.
27. The Pioneer Corporation Co., Pioneer Eradium Luminous Matchbox [advertisement]. Hammer. Box 65:10.
28. Advertising card, "Radium Rays Made Visible," Bailey Radium Laboratories, circa 1925. AMA. Box N1.
29. American Radium Corporation [business card], undated (circa 1929). AMA. Box 719:8.
30. Radior Co. of London, "Radium and Beauty" [advertisement], undated (circa 1918), 6. AMA. Box 720.
31. Ibid., 11.
32. Advertisement, Narada Radium Preparations, circa 1930. ORAU (Oak Ridge Associated Universities).
33. It was also as specious as the other claims made for radioactive cosmetics: Narada, a product of the Denver Radium Laboratories, was tested for radium content by the AMA in 1938, and found to contain far less than the manufacturers specified. "Denver Radioactive Products Not Acceptable," *Journal of the American Medical Association* 111, no. 18 (October 29, 1938): 1655–1656.
34. Radior Co. of London, "Radium and Beauty," back cover.
35. See, for example, the following FTC press releases regarding radium products: "'Radio-Active' Healing Comes Under Advertising Ban" (June 4, 1931); "'Radio Activity' Advertisements Undergo Correction" (June 4, 1931); "Advertising Copy for 'Water Revitalizer' Is Changed" (May 26, 1931). CRI. Box 448, folder "Radium Nostrums and Radium Water Machines—Misc., 1930–1939."
36. "Wayward Wisdom on Ancient Spheres," *Golf*, April 1992. ORAU.

37. Edward Gerson, "X-Ray Mania: The X Ray in Advertising, Circa 1895," http://radiographics.rsnajnls.org/cgi/content/full/24/2/544.
38. Radium Mines Company [advertisement], *Field And Fancy Magazine*, May 6, 1921.
39. Radio-Active Chemical Company of Denver [advertising pamphlet], undated. AMA. Box 720:5.
40. Radium Fertilizer Company [advertisement], *Washington Post*, April 25, 1915.
41. J. J. Thomson, "Radio-active Gas from Well Water," *Nature* 67, April 30, 1903, 609.
42. Carolyn Thomas de la Peña has observed that, at the turn of the twentieth century, the prominent Fordyce Bath House at Hot Springs, Arkansas, successfully melded a sleek, ostentatiously modern aesthetic with the traditional understanding of a spa cure, appealing to patients' desire for the potential revivification that impressive hydrotherapeutic and electrotherapeutic equipment promised while allowing a veneer of the traditional bucolic setting to blunt the anxiety that attached to new technology in general at the time. Where radioactivity was concerned, however, the rhetoric of modernity is seldom found. Advertisements dwelling on the radioactive virtues did not use words like "balneology" and "hydrotherapy," but typically invoked science only in the person of the geologist or chemist that had certified a place's waters to be radioactive. Carolyn Thomas de la Peña, "Recharging at the Fordyce: Confronting the Machine and Nature at the Modern Bath," *Technology and Culture* 40, no. 4 (October 1999): 746–769.
43. Hot Springs National Park [advertisement], *Minneapolis Journal,* January 12, 1931. The second excerpt is from an ad reproduced in Hot Springs Chamber of Commerce [internal memorandum], Garland County Historical Society, Box 30, binder labeled "Chamber of Commerce, Paid Advertising, 1929–1934."
44. As chapter 2 notes, places from Georgia to Quebec and Tennessee to Connecticut had experienced brief frenzies over spurious reports of local veins of radium-bearing ore, but nothing suggests that any such place acquired a radioactive reputation outside of its own borders.
45. Gregg Mitman and Ronald A. Numbers, "From Miasma to Asthma: The Changing Fortunes of Medical Geography in America," *History and Philosophy of the Life Sciences* 25 (2003): 399.
46. For example, an FTC report from July 29, 1938 (*In re: H.R. Zimmer, Docket No. 2862*) asserts that Zimmer's emanator is falsely advertised as containing "pure refined radium," as opposed to unrefined ore.
47. Radium Ore Revigator Company [advertisement], circa 1927. AMA. Box 723:3.
48. Radium Ore Revigator [owner's manual], circa 1926. AMA. Box 723:2.

49. Radium Ore Revigator Company [advertisement], circa 1925. AMA. Box 723:1.
50. Radium Spä [advertising pamphlet], undated (circa 1920). ORAU.
51. Letter, Radium Ore Revigator Company to Hotels Statler Co., September 4, 1925. AMA. 723:1.
52. Radium Ore Revigator Agency, New Orleans [advertising pamphlet], undated (circa 1930). ORAU. The relevant text reads, "There Are Now Over 500,000 Satisfied Revigator Users," followed by a list of consumers local to the New Orleans area.
53. The AMA received many letters of inquiry from patients whose doctors had recommended (or sold) emanators to them. AMA. Box 723.
54. Radioak [advertisement], circa 1925. AMA. Box 720:19.
55. Samuel Hopkins Adams, *The Great American Fraud: Articles on the Nostrum Evil and Quacks, in Two Series, Reprinted from Collier's Weekly* (San Francisco: P. F. Collier, 1907), 91–93.
56. American Medical Association, *Nostrums and Quackery* (Chicago: American Medical Association Press, 1912), 70–75.
57. The substance is also referred to by E. Stillman Bailey and others as "Radia-thor," "Radio-thor," and "Radio-Thor-X," as well as by various spellings and hyphenations of "thoradx." Because *William* Bailey (described below) subsequently named his tonic *Radithor*, perhaps with every intention of creating this sort of confusion, I have avoided using those names for Stillman Bailey's substance.
58. "A Radium Substitute," *New York Tribune*, July 13, 1910, 5.
59. "Tells of Ra-Dia-Thor," *Indianapolis Star*, February 26, 1909.
60. E. Stillman Bailey, "Radium and Radiotorium," *The Clinique* 34, no. 5 (May 1913): 243.
61. "Dr. Bailey's Radium Potency Treatment," advertisement. AMA. Box 920:15.
62. Home Products Company of Denver, "Weak Discouraged Men!" [advertisement] (September 29, 1930). ORAU. The document is a reproduction by the Museum of Questionable Medical Devices of an item held by the American Medical Association.
63. Radium Appliance Co. of Los Angeles [advertisement], circa 1930. AMA. Box 719:1.
64. American Radium Company, "Radium, the Master Key to Health, Youth and Beauty" [advertising folio], circa 1925. AMA. Box 719:8.
65. Bailey Radium Laboratories, "Perpetual Sunshine," advertising pamphlet, circa 1928. ORAU.
66. Bailey Radium Laboratories, "What Happened to the Spaghetti?" advertising pamphlet, circa 1928. AMA. William J. A. Bailey, Names Files, Box N1.
67. Adrenoray Company, "The Adrenoray," advertising pamphlet, circa 1931. ORAU.
68. American Endocrine Laboratories, "Scientific Control over Physical Energy, Character, Looks, and Memory By the Application of Gamma

Rays to the Endocrine Glands," advertising pamphlet, circa 1930. ORAU.

69. Adrenoray Company, "The Adrenoray."
70. I reviewed the following journals, during the portion of their periods of publication that fell between 1900 and 1945: *School Science and Mathematics*, *School Science Review*, *Science Education*, *General Science Quarterly*, and *The School Review*.
71. John W. Schneck and Francis D. Curtis, "The Important Scientific Terms in High-School Physics," *The School Review* 50, no. 10 (December 1942): 715–720.
72. C. H. Nettels, "Science Topics That Are of Interest and Use to Adults," *Science Education* 15, no. 3 (March 1931): 139–145.
73. C. H. Nettels, "Science Interests of Junior-High School Pupils," *Science Education* 15, no. 4 (June 1931): 219–225.
74. Gerald W. Fox and D. L. Rich, "An Investigation of the Attitude of Physics Teachers Toward the Content of the High School Physics Course," *Science Education* 15, no. 1 (1930): 9–13.
75. Earl R. Glenn, "Recent Discoveries Concerning X-Rays," *School Science and Mathematics* 15 (1915): 563.
76. Ira Remsen, *An Introduction to the Study of Chemistry*, 6th ed. (New York: Henry Holt, 1902), 396.
77. Charles Riborg Mann and George Ransom Twiss, *Physics* (Chicago: Scott, Foresman, 1906), 441.
78. Joseph S. Ames, *Textbook of General Physics for High Schools and Colleges* (New York: American Book, 1904), 700–707.
79. Harry C. Biddle and George L. Bush, *Dynamic Chemistry* (New York: Rand McNally, 1937), 747.
80. Charles Dull, *Modern Chemistry* (New York: Henry Holt, 1944), 535.
81. B. S. Hopkins, H. R. Smith, R. E. Davis, Martin V. McGill, and G. M. Bradbury, *Chemistry and You: A Textbook for High Schools* (Chicago: Lyons and Carnahan, 1944), 349–351.
82. Ibid., 348.
83. Louis Heil, *The Physical World* (Philadelphia: P. Blakiston's Son, 1936), 11.
84. Overton Luhr, *Physics Tells Why: An Explanation of Some Common Physical Phenomena* (Lancaster, PA: Jacques Cattell, 1943), 288, 291–292.
85. Joseph Cottler and Haym Jaffe, *Heroes of Science* (Boston: Little, Brown, 1931), 76–79.
86. N. Henry Black and James Bryant Conant, *Practical Chemistry: Fundamental Facts and Applications to Modern Life* (New York: Macmillan, 1920), 457.
87. Carlotta C. Greer and J. Cora Bennett, *Chemistry for Boys and Girls* (Boston: Allyn and Bacon, 1925), 198–199.
88. Ronald Tobey, *The American Ideology of National Science: 1919–1930* (Pittsburgh: University of Pittsbugh, 1971), 10.

89. James Steel Smith, "The Day of the Popularizers: The 1920's," *The South Atlantic Quarterly* 62 (Spring 1963): 297–299.
90. V. E. Pullin and W. J. Wiltshire, *X-Rays Past and Present* (New York: Van Nostrand, 1927), 9.
91. See chapter 2 for a fuller discussion of these organizations.
92. James Kendall, *At Home Among the Atoms: A First Volume of Candid Chemistry* (New York: Century, 1929), ix.
93. Robert Kennedy Duncan, *The New Knowledge: A Popular Account of the New Physics and the New Chemistry in Their Relation to the New Theory of Matter* (New York: A. S. Barnes and Company, 1905), vii–viii, xv.
94. W. Hampson, *Radium Explained: A Popular Account of the Relations of Radium to the Natural World, to Scientific Thought, and to Human Life* (New York: Dodd, Mead and Company, 1905), ix.
95. Oliver Lodge, *Atoms and Rays: An Introduction to Modern Views on Atomic Structure and Radiation* (New York: George H. Doran, 1924), v.
96. Watson Davis, *The Advance of Science* (Garden City: Doubleday, Page, 1934), 71.
97. Carl T. Chase, *Frontiers of Science* (New York: D. Van Nostrand, 1936), 184.
98. Waldemar Kaempffert, *Science Today and Tomorrow* (New York: Viking Press, 1939), 110–111, 127.
99. Benjamin Gruenberg, *Science and the Public Mind* (New York: McGraw-Hill Book, 1935), 19.
100. David Dietz, *The Story of Science* (New York: Sears Publishing, 1931), 201.
101. David Rhees, *A New Voice for Science: Science Service under Edwin E. Slosson, 1921–29* (MA thesis, University of North Carolina-Chapel Hill, 1979), 19; Bruce Lewenstein, *Public Understanding of Science in America* (PhD diss., University of Pennsylvania, 1987), 228.
102. The term "fanzines" is the one preferred by their authors. The most comprehensive collections of fanzines, which have resisted full integration into bibliographies because of their rarity and (often) their consignment to restricted collections on the grounds of fragility, can be found in two archives: the Paskow Science Fiction Collection of the Paley Library of Temple University in Philadelphia, and the Williamson Science Fiction Library of Eastern New Mexico University-Portales.
103. Fredric Wertham, *The World of Fanzines* (Carbondale, IL: Southern Illinois University Press, 1973), 38–39.
104. *Science Fiction Critic* 1, no. 11 (October 1937): Front cover. Paskow.
105. For the symbiotic relationship and often barely discernable boundary between fans (and fanzines) and the professional publications, see also Sam Moskowitz, "The Origins of Science Fiction Fandom:

A Reconstruction," in *Science Fiction Fandom*, Joe Sanders, ed. (New York: Greenwood Press, 1994), 17–36.

106. Raymond Z. Gallun, letter to *Stardust* 2, no. 1 (September 1940): 6. Williamson.
107. The *Science Correspondence Club Organ*, also known as *Cosmology*, of which two issues (1930 and 1931) survive in the Paskow collection, is typical. In his page one "Dedication" of the latter issue, Club President Frank B. Eason, Sr., linked the work of "Jeans, Shapley, Eddington, Einstein, Steinmetz and others" to the "young [fiction] authors of today who are following in the footsteps of the great men. They are playing a highly important part in the promotion of science. They are placing before the public in fiction, stories, which Jules Verne's may equal, but never surpass, and in a great many instances will not equal." But the remainder of the issue was nonfiction essays on general-interest topics in science.
108. Burris Cunningham, *Science Wonder Stories* 1, no. 2 (July 1929): 283–284.
109. Ibid., 280.
110. Irvin Fletcher and Lester Pratt, "Reign of the Ray," *Science Wonder Stories* 1, no. 1 (June 1929): 12–13.
111. J. P. Marshall, "Warriors of Space," *Science Wonder Stories* 1, no. 1 (June 1929): 39.
112. Kennie McDowd, "The Marble Virgin," *Science Wonder Stories* 1, no. 1 (June 1929): 58.
113. Stanton A. Coblentz, "The Making of Misty Isle," *Science Wonder Stories* 1, no. 1 (June 1929): 76.
114. Jack Williamson, "Tremendous Contribution to Civilization," *Science Wonder Stories* 1, no. 1 (June 1929): 89. Note that this young fan is the same Jack Williamson who would, more than half a century later, endow the Williamson Science Fiction Library at Eastern New Mexico University-Portales.
115. Henry Gade, "Radium Airships of Saturn," *Amazing Stories* 16, no. 7 (July 1942): Back cover and 270–271.
116. See, for example, Charles E. Gannon, *Rumors of War and Infernal Machines: Technomilitary Agenda-Setting in American and British Speculative Fiction* (Liverpool: Liverpool University Press, 2003), 91–93.
117. Herbert George Wells, *The World Set Free* (London: Collins' Clear-Type Press, 1921). This edition has been transcribed as an electronic text available through Project Gutenberg at gutenberg.org.
118. "War Map Business Has a Great Boom," *New York Times*, August 30, 1914, 8.
119. Paul A. Carter, *The Creation of Tomorrow: Fifty Years of Magazine Science Fiction* (New York: Columbia University Press, 1977), 125.
120. Martha A. Bartter, *The Way to Ground Zero: The Atomic Bomb in American Science Fiction* (New York: Greenwood Press, 1998), 22–24, 29–31, 77.

121. Arthur Train and Robert Williams Wood, *The Man Who Rocked the Earth* (Gatden City: Doubleday, Page, 1915); Hollis Godfrey, *The Man Who Ended War* (Boston: Little, Brown, 1908).
122. Edith MacVane, "The Radium Robbers," *McClure's Magazine* 48, no. 3, July 1914, 64.
123. George Allen England, *The Golden Blight* (New York: H. K. Fly, 1916), 56.
124. Sam Moskowitz, *Science Fiction by Gaslight* (Westport, CT: Hyperion Press, 1974), 141.
125. Albert Dorrington, *The Radium Terrors: A Mystery Story* (New York: W. R. Caldwell, 1912).
126. There were several real-life clinics by that name, or ones very similar to it, in America at the time.
127. Hugo Gernsback, editorial commentary to John Campbell, "Space Rays," *Science Wonder Stories* 4, no. 7 (December 1932): 585.
128. Lester del Rey, *The World of Science Fiction, 1926–1976: The History of a Subculture* (New York: Garland Publishing, 1980), 73.
129. P. H. D., "The President," *Boston Sunday Post*, July 26, 1903.
130. W. R. [*sic*], "The Song of Radioactivity," *Popular Mechanics*, June 1911, inside front cover.
131. Mina Loy, "Gertrude Stein," *The Transatlantic Review* 2, no. 3, September 1924, 305.
132. R. H. Law, "Radium," *Living Age* 241, May 7, 1904, 384.
133. Charles Kelsey Gaines, untitled poem. Reprinted in "Madame Curie at the St. Lawrence University, October 25 and 26, 1929." Columbia. Box 5.
134. Barbara Goldsmith, *Obsessive Genius: The Inner World of Marie Curie* (New York: W. W. Norton & Company, 2005), 193.
135. Susan Quinn, *Marie Curie: A Life* (New York: Simon & Schuster, 1995), 386.
136. Françoise Giroud, *Marie Curie, a Life* (New York: Holmes and Meier, 1986), 238.
137. Robert Reid, *Marie Curie* (London: Collins, 1974), 263.
138. Robert A. Millikan, "Speech on Radium," typewritten MS, archivally dated 1921. SIA. Record Unit 7091, Box 9:4.
139. Cf. *Selections from the Scientific Correspondence of Elihu Thomson*, Harold J. Abrahams and Marion B. Savin, eds. (Cambridge, MA: MIT Press, 1971).
140. "No Danger in Being X-Rayed," *The Literary Digest*, July 16, 1921, 23.
141. "Edison Tells of New Value of X-Ray," *Fort Wayne* [Indiana] *Sentinel*, August 4, 1903, 7.
142. "Edison Fears Hidden Perils of the X-Rays" *New York World*, August 3, 1903, 1.
143. See, for example, "Protege of Edison Killed by X-Rays," *Post-Standard* [Syracuse, New York], October 4, 1904, 1.
144. "Martyrs to Science," *Washington Post*, December 12, 1909, 14.

145. "X-Rays Killing Expert: Burns Received in Practice Killing Physician," *Washington Post*, July 12, 1910, 1; "Famed Expert Is Dying from X-Ray Burns He Was Called to Trenton to Disprove," *Trenton Evening Times*, July 12, 1910, 1.
146. Rebecca M. Herzig, *Suffering for Science: Reason and Sacrifice in Modern America* (New Brunswick, NJ: Rutgers University Press, 2005), 98–99.
147. Cf. "Martyrs to Science Give Their Lives to Benefit Humanity," *San Antonio Light*, February 22, 1929, 17B.
148. "Carnegie Hero Medal Honors X Ray Martyr," *Washington Times*, May 25, 1914, 4.
149. Cf. "Dr. George H. Stover," *American Journal of Roentgenology* 2, no. 4 (February 1915): 659.
150. Catherine Covert, "Freud on the Front Page: Transmission of Freudian Ideas in the American Newspaper of the 1920's" (PhD diss., Syracuse University, 1975). See also a discussion of Covert's model in John Burnham, *How Superstition Won and Science Lost* (Brunswick, NJ: Rutgers University Press, 1987), 39–40.
151. Source: *New York Times*, *Los Angeles Times*, and *Chicago Daily Tribune*. Keyword search on Proquest Historical Newspapers, limited to titles and abstracts of news articles, for the following terms: x-ray, x ray, Roentgen ray, Röntgen ray, radium, thorium, uranium, polonium, radon, radioactivity, radio-activity, atomic. (Excludes the *Los Angeles Times*' recurring column "The Sports X-Ray.")
152. E. E. Slosson and G. Coutremoulius, "X-Rays May Endanger the Neighbors," typewritten MS dated May 12, 1921. SIA. Record Unit 7091, Box 367:2.
153. "A Burnless X-Ray," *The Independent*, August 30, 1915, 300.
154. Woods Hutchinson, "Heroes of the X Ray," *Youth's Companion* 96, no. 10, March 9, 1922, 132.
155. This is, in any event, the contention of Burnham in *How Superstition Won and Science Lost*. Many historians have subsequently taken issue with his relatively unilateral understanding of the process of science popularization, but not with the underlying assessment of who was engaged in popularizing when.
156. Burnham, *How Superstition Won and Science Lost*, 199.

4 Backlash

1. See, for example, Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910–1935* (Chapel Hill, NC: University of North Carolina Press, 1997); Ross Mullner, *Deadly Glow: The Radium Dial Worker Tragedy* (Washington, DC: American Public Health Association, 1999), 94–96.
2. William Kovarik, "The Radium Girls," in *Mass Media and Environmental Conflict*, William Kovarik and Mark Neuzil, eds.

(Thousand Oaks, CA: Sage Publications, 1996). Cf. revised edition (2002), http://www.runet.edu/%7Ewkovarik/envhist/radium.html. Accessed December 11, 2011.

3. Cf. Mullner, *Deadly Glow*, 94–96.
4. "Radium Case Aids Science," *Newark* [New Jersey] *Evening News*. Undated clipping, circa December 9, 1929. Martland.
5. "Inventor Dies, Victim of His Radium Paint," news clipping, dated November 15, 1928. Martland.
6. Catherine Caufield, *Multiple Exposures: Chronicles of the Radiation Age* (New York: Harper & Row, 1989), 37.
7. "Semi-legitimate" because of a history of deceptive trade practices that make him appear a questionably honest businessman at best and a con artist at worst (See chapter 3). Bailey's personal enthusiasm for radium, however, appears to have been genuine, and in any event there is absolutely no doubt about the potency of Radithor, the surviving bottles of which are invariably still radioactive.
8. "Radium Tonic Suspected as Bennett, Insurance Man, Dies," newspaper clipping dated May 29, 1937. Martland. Radium Scrapbook VI:14.
9. "Death Stirs Action on Radium 'Cures,'" *New York Times,* April 2, 1932, 12.
10. Ron Winslow, "The Radium Water Worked Fine Until His Jaw Came Off: Cancer Researcher Unearths a Bizarre Tale of Medicine and Roaring '20s Society,'" *Wall Street Journal*, August 1, 1990, A1.
11. "Radium Drinks," *Time*, April 1, 1932, 48–49.
12. See, for example, F. J. Schlink to John Christensen (Ossining, NY), June 15, 1934. CRI. Box 448.
13. Congressional Record (reprint) of the 72nd Congress, 1st Session. April 29, 1932.
14. Transcript of "Uncle Sam at Your Service," USDA Radio Service Bulletin #9630 (November 16, 1935). CRI. Box 448.
15. "Marie Curie," *New York Times,* July 5, 1934. Section 8, 9.
16. American Institute of Physics (AIP), "The Radium Institute (1913–1914)," http://www.aip.org/history/curie/radinst3.htm. Accessed November 15, 2011.
17. Robert D. Potter, "Pernicious Anemia Caused by Years of Research on Radium Killed Madame Curie," typewritten copy of Science Service wire report (July 5, 1934). SIA. Record Unit 7091, Box 373:27.
18. Jacalyn Duffin and Charles R. R. Hayter, "Baring the Sole: The Rise and Fall of the Shoe-Fitting Fluoroscope," *Isis* 91, no. 2 (June 2000): 281.
19. "Tricho System Awarded Grand Prize at Paris Exposition," *The Business Survey*, November 25, 1925.
20. David J. DiSantis and Denise M. DiSantis, "Radiologic History Exhibit: Wrong Turns on Radiology's Road of Progress," *RadioGraphics* 11, no. 6 (November 1991): 1126.

21. "The Tricho System," *Better Business Bureau Bulletin (Indianapolis)* 2, no. 29 (July 17, 1930): 299.
22. Tricho System [advertisement], "Tricho System Endorsed by the Medical Professional," undated. Reproduced in a pamphlet by the Museum of Questionable Medical Devices. ORAU.
23. "Tricho System Awarded Grand Prize at Paris Exposition." Emphasis added.
24. "Tricho System Endorsed by the Medical Professonal."
25. Rebecca Herzig, "Removing Roots: 'North American Hiroshima Maidens' and the X Ray," *Technology and Culture* 40, no. 4 (1999): 737–740.
26. "New Use for Roentgen Rays! University Professor Perfects Mechanical Method Which Bids Fair to Remove One Curse of Mankind," *Evening Mail*, January 29, 1923.
27. "Hair Removed Permanently," advertisement for the Tricho System, *Chicago Tribune*, June 15, 1928; "Now It Is So Easy to Have Faultless Skin," advertisement for the Tricho System, *New Haven Register*, February 19, 1925.
28. "The Tricho System," *JAMA* 92 (January 19, 1929), 252.
29. Albert C. Geyser, "Facts and Fallacies about the Removal of Superfluous Hair," advertising pamphlet for the Tricho System circulated in Evansville, IN, n.d. AMA. Box 0317–17.
30. George L. Burkle (National Better Business Bureau) to AMA, (May 21, 1930). AMA. Box 0318–06.
31. "The Tricho System," *JAMA*. On a California Tricho licensee being found guilty of practicing medicine without a license, see C. B. Pinkhan (AMA) to To C. Guy Lane (American Dermatological Association) (May 29, 1930). AMA. Box 318–05.
32. "Experiences of Cleveland Better Business Bureau with Local Tricho System Office," typewritten MS, archivally dated January 12, 1931. AMA. Box 0317–17.
33. For example, see the letter of G. V. Stryker in *JAMA* 92 (March 16, 1929), 319. It related a patient's encounter in which "the attendant in charge of these treatments has repeatedly denied to the patient that she was using x-rays."
34. Ray-X water [advertisement], circa 1932. CRI. Box 448, folder "Radium Nostrums and Radium Water Machines A-Z, 1930–1939."
35. Cf. "'Ray-X Water—Liquid Sunshine:' Another Attempt to Make a 'Patent Medicine' Out of Drinking Water," *Journal of the American Medical Association* 99 (August 6, 1932): 493. See also the testimonial letter from "R. A. Davis, M. D." of Detroit to the Ray-X Water Corporation, dated April 23, 1932, which Ray-X quoted from in their literature. CRI. Box 448.
36. Claremore Radium Water Crystals, "Drink Radium Water Crystals" [advertisement], circa 1932. CRI. Box 448.

37. R. N. Brainerd to Harrison Martland [letter], October 18, 1931. Martland.
38. Letter, H. R. Zimmer to Harrison Martland, February 26, 1932. Martland. Radium Scrapbook V:7.
39. Advertising pamphlet, Radiumac Mineral Co., archivally dated December 23, 1931. AMA. Box 721:1.
40. E[mmons] R[utledge] Booth, *History of Osteopathy and Twentieth-Century Medical Practice*, 2nd ed. (Cincinnati: Caxton Press, 1924), 349, 372. The text quoted above is unchanged from the 1905 edition.
41. Otto Juettner, *Modern Physio-Therapy: A System of Drugless Therapeutic Methods, Including a Chapter on X-Ray Diagnosis* (Cincinnati: Harvey, 1906), 3.
42. Albert Abrams, *Diagnostic Therapeutics: A Guide for Practitioners in Diagnosis by and of Drugs and Methods Other Than Drug-Giving* (New York: Rebman, 1910), 180.
43. Tilman Howard Plank, *A Treatise on Actinic-Ray Therapy, for Physicians Interested in Physical Therapeutics* (Chicago: Manz Corporation, 1919), 16.
44. See for instance William Beaumont, *Infra-Red Radiation* (London: H. K. Lewis, 1936).
45. Bakken. Artifact collection. Emphasis in original.
46. Baker Hospital of Muscatine, "Cancer is Curable—Without Operation, X-Ray, or Radium: A Challenge to the American Medical Association, All Health Departments, and Scientists" [advertising pamphlet], 5. United States National Library of Medicine (NLM).
47. "Radium Ore Revigator: Capitalizing on the Public's Ignorance of Radium and Radioactivity," *Journal of the American Medical Association* 85, no. 21 (November 21, 1925): 1658.
48. One such letter is an unsigned response to the August 18, 1931 inquiry of Edward Messler, whose doctor was suggesting that he buy a Revigator. AMA. Box 723:6.
49. S. Russ and Hector A. Colwell, *X-Ray and Radium Injuries: Prevention and Treatment* (London: Oxford University Press, 1935), 185.
50. This exemplary quotation is taken from a letter by B. O. Halling, Bureau of Investigation, to Ludwig Johnson of Oak Park, Illinois (May 22, 1925) regarding purportedly radioactive compresses sold by the Denver Radium Service. AMA. Box 185:19.
51. See, for example "Radioactive drinking waters," *Hygeia* 7, October 1929, 1023–1024; "X-rays and Radium, Their Use and Abuse," *Hygeia* 10, July 1932, 632.
52. M. Mok, "Radium, Life-Giving Element, Deals Death in Hands of Quacks," *Popular Science Monthly* 131, July 1932, 9–11, 105–106.
53. "Byers' Fate Causes Norris to Warn Against Quackery," *New York American*. Undated photocopy. Martland. Radium Scrapbook V:12.

54. Milton Bronner, "Mantle of Greatest Woman on Daughter's Shoulders," *Spartanburg Herald-Journal*, August 12, 1934, 4.
55. "Surgical Use of X-Ray, Radium Will Be Shown," *Chicago Daily Tribune,* July 27, 1931, 17.
56. Jordan D. Marché II, *Theaters of Time and Space: American Planetaria 1930–1970* (New Brunswick, NJ: Rutgers University Press, 2005), 80. Chapter four ("The Empire of Science") of Robert Rydell, *World of Fairs: The Century-of-Progress Expositions* (Chicago: University of Chicago Press, 1993) puts the cosmic ray stunt in a broader context and is an excellent primer on representations of science at the fairs.
57. "Free X-Ray Pictures Given to Visitors," *New York Times*, May 17, 1939, 42.
58. "X-Ray Lamp Puts Aladdin to Shame," *New York Times*, July 22, 1939, 4.
59. "Uncle Sam At Your Service."
60. "Timely Technicalities," *The Glass Packer* (June 1937), 394. CRI.
61. Letter, Leonard Loeb to F. J. Schlink of the Consumer Research Institute, March 29, 1937. Some of Loeb's distress stemmed from the fact that thorium is poisonous even without taking the effects of radioactivity into account. CRI. Box 448, folder "Radium Nostrums and Radium Water Machines—Misc., 1930–1939."
62. Federal Trade Commission, "Bulletin" [internal memorandum], March 1930. CRI. This particular bulletin was reprinted in the "Current Science Comment" column of the *Chicago Tribune*, March 20, 1930.
63. "Can The Ethiopian Change His Skin or the Leopard His Spots?," *Boston Globe,* January 25, 1904. For more on the subject of race and radiation, see Carolyn Thomas de la Peña, "Bleaching the Ethiopian: Desegregating Race and Technology through Early X-Ray Experiments," *Technology and Culture* 47 (2006): 27–55.
64. Elof Carlson, *Genes, Radiation and Society: The Life and Work of H. J. Muller* (Ithaca, NY: Cornell University Press, 1981), 150.
65. "Cosmic Rays and Evolution," *New York Times*, April 26, 1928, 26.
66. Waldemar Kaempffert, "A Biologist's View of Man's Future," *New York Times*, March 15, 1936, BR4.
67. Ed Earl Repp, "The Radium Pool," *Science Wonder Stories* (July and August 1929).
68. Alexander Snyder, "Blasphemer's Plateau," *Amazing Stories* 1, no. 7 (October 1926): 656–671. See also Edmond Hamilton, "The Man Who Solved Death," *Science Fiction* 1, no. 3 (August 1939): 82–86.
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70. John L. Chapman, "Cycle," *Marvel Science Stories* 2, no. 2 (November 1940): 106–112.
71. Warren Sanders, "The Sterile World," *Wonder Stories Quarterly* 3, no. 3 (Spring 1932): 408.

72. "Cosmic Forces Alter Insects," *New York Times*, October 17, 1929, A10.
73. "Universe Not Running Down, Dr. Millikan Says," *Painesville Telegraph*, December 30, 1930, 1.
74. "Debate Fails to Clear Up Cosmic Rays," *Pittsburgh Post-Gazette*, December 31, 1932, 2.
75. "Predicts N. Y. to Berlin Flights in Eight Hours," *Lewiston Daily Sun*, June 1, 1931, 12.
76. Cf. Lawrence Badash, Elizabeth Hodes, and Adolph Tiddens, "Nuclear Fission: Reaction to the Discovery in 1939," *Proceedings of the American Philosophical Society* 130, no. 2 (June 1986): 212.
77. "Want To Split an Atom? Here's Way To Do It," *Chicago Tribune*, May 6, 1932, 16.
78. Waldemar Kaempffert, "Rutherford Cools Atom Energy Hope," *New York Times,* September 12, 1933, 1.
79. "Atomic Power Again," *New York Times*, May 7, 1940, 23.
80. "'Molecule Murder' Seen by Scientists," *New York Times*, July 23, 1932.
81. William Laurence, "The Atom Gives Up," *Saturday Evening Post,* September 7, 1940, 12–13. Interestingly, in an article that explicitly frames the work of refugee scientists like Bohr and Meitner as a race against Germany, and which is otherwise littered with references to explosions and the enormous amounts of energy in tiny fragments of uranium, the bomb-making potential of such a process is never explicitly addressed.
82. "No Terrestrial Catastrophe Likely to Occur as Result of Atom-Smashing Experiments," *Washington Post*, February 19, 1939, 7.
83. Edward P. Sumers, *Science Fiction Magazine* 2, no. 4 (April 1941): 59.
84. Robert Heinlein, "Blowups Happen," *Astounding Science Fiction* 25, no. 7 (September 1940): 61–62.
85. John Clute and Peter Nichols, *The Encyclopedia of Science Fiction* (New York: St. Martin's Press, 1993).
86. Alan L. Hart, *These Mysterious Rays: A Nontechnical Discussion of the Uses of X-Rays and Radium, Chiefly in Medicine* (New York: Harper, 1943), 151.
87. Henry K. Pancoast, "The Therapeutic Effects of the X-Rays, as Shown from the Results of Treatment of Nearly One Hundred Cases," *Archives of Electrology and Radiology* 4 (1904), 123–129.
88. F. S. O'Hara, "Looking Backward," *Radiography & Clinical Photography* 8 (May–June 1932): 5. "Baking" a tube meant heating it in an oven to release gas back into a tube that had been "hardened" by use (that is, the tube's vacuum had become too high from the action of the cathode rays on the gases and tube walls). It was a delicate process, necessary because of the expense of replacing tubes outright, but it added one more layer of complexity for doctors and

one more variable to the performance of the tubes: a tube performed very differently before and after being "baked."

89. Hart, *These Mysterious Rays*, 26.
90. F. L. Pengelly, untitled typewritten ms, n.d. ACR. Box 531. Emphasis added.
91. John F. McCullough, "Early History of Radiology in Pittsburgh," interview with Lewis Etter (May 29, 1960), 2. ACR. Box 531.
92. Acme-International X-Ray Co., advertising pamphlet titled "Acme-International 120 K.V. Roentgen Generator," September 15, 1926. ACR. Box 653.
93. Anderson, Norden & Co., photocopied pamphlet, 1907. ACR. Box 655.
94. Acme-International X-Ray Co., "Acme-International 120 K.V. Roentgen Generator."
95. Acme-International X-Ray Co., advertising pamphlet titled "Precision Mobile X-Ray Apparatus," April 1928. ACR. Box 653.
96. Acme-International X-Ray Co., advertising pamphlet titled "Precision Coronaless Deep Therapy Apparatus," n.d. (circa 1928). ACR. Box 653.
97. "High-Powered X-Rays," transcript of *Science Service Radio Broadcast* (February 10, 1938). SIA. Record Unit 7091, Box 373:27.
98. Israel Klein, "Science Tries to Equal Radium's Terrific Power by Electricity," *NEA Service* (January 5, 1928).
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5 Toward the Second Atomic Age

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2. Cleveland Moffett, "The Wonders of Radium," *McClure's Magazine* 22, no. 1, November 1903, 7.
3. Paul Boyer, *By The Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Chapel Hill, NC: University of North Carolina, 1994), 3.
4. Boyer, 65–75.
5. Boyer, 112.
6. John Percival Lord, *Radium* (London: Harding Bros, 1910), 53.

7. No serious claim that the United States (or anyone else) could prevail in a nuclear war was ever publicly advanced by the government throughout the Cold War; even the most ardent advocates of the "Star Wars" missile defense system expressed its value in terms of its deterrent capabilities. The massive bilateral buildup in weapons that happened over the course of the 1950s and 1960s was not the result of any popular insistence on nuclear dominance, but rather the result of internal political dynamics in both the United States and the Soviet Union. See Richard Rhodes, *Arsenals of Folly: The Making of the Nuclear Arms Race* (New York: Knopf, 2007).
8. Eisenhower's address to the four hundred and seventieth Plenary Meeting of the United Nations General Assembly (December 8, 1953), is archived at http://www.world-nuclear-university.org/about.aspx?id=8674.
9. Richard Feynman relates the amusing story of the government's scramble, at the close of the war, to place under patent protection broad swathes of potential nuclear technologies, including a nuclear airplane of which he (a theoretical physicist) was the nominal inventor. Feynman and Ralph Leighton, *Surely You're Joking, Mr. Feynman! Adventures of a Curious Character* (New York: W. W. Norton, 1997), 180–183.
10. Or, as some had it at the time, the "Pan-Atomic Canal."
11. Herman Kahn, *On Thermonuclear War* (New Brunswick, NJ: Transaction Publishers, 2007), 483–484.
12. Frederick Soddy, *The Interpretation of Radium, Being the Substance of Six Free Popular Experimental Lectures Delivered at the University of Glasgow, 1908* (London: John Murray, 1909), 251.
13. See Scott Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, NJ: Rutgers University Press, 2005).
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22. "Fact is Stranger Than Fission," *Saturday Evening Post,* September 2, 1945, 4.
23. "Bombs Away," *Fitchburg Sentinel*, August 27, 1945, 6.
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27. Waldemar Kaempffert, "First Direct Use of Atomic Energy Sets Up Electric Current, Small but Prophetic," *New York Times*, January 31, 1951, E9.
28. Waldemar Kaempffert, "When Uranium Splits: Doubtful Source of Power," *New York Times*, March 5, 1939, D9. Cf. Spencer Weart, *Nuclear Fear: A History of Images* (Cambridge, MA: Harvard University Press, 1988), 81.
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Index