Harnessing the Modern Miracle:
Physicists, Physicians, and the Making of American Radium Therapy

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Abstract

At the beginning of the twentieth century, the newly-discovered element radium was at the center of a storm of public fascination and was touted as a cure for all manner of ailments by patent medicine sellers. By the early 1930s, radium was the foundation of a standard cancer therapy in hospitals. How this transformation occurred, and the physicians and physicists who led that development, are the subject of this dissertation. Early adopters of radium therapy appropriated knowledge, material, and practices from physics as they integrated radium into their practices. Starting in the mid-1910s, even as the long-term dangers of radium were becoming apparent, radium therapy moved into the hospital, in large part because of new equipment adapted from the physics laboratory, and radium therapists invited physicists into the hospital as key collaborators in standardized radium therapy.

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Introduction

What is Radium Therapy?

> Because of the very remarkable physical properties of radium, and the fact that its discovery compelled the revision of previously existing notions regarding the composition of matter, the structure of the molecule and atom and the relation of electricity to matter, it is not surprising to find that physicists and physicians worked hand in hand in treating the earliest cases.
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> —Carroll Chase, "American Literature on Radium and Radium Therapy Prior to 1906," *American Journal of Roentgenology, Radium Therapy and Nuclear Medicine* 8 (1921): 766.

Outline of the Dissertation

Radium is an extraordinary element: discovered in 1898, it was the most radioactive substance then known and it was at the center of a nearly unprecedented storm of popular interest at the dawn of the century. It also had marked effects on the body and was quickly brought into therapeutic use. Over the first three decades of the twentieth century, radium had a home both in the physics laboratory and the clinic. Scientific developments shaped the ways the new element was understood and used in therapy. In America in the first decade of the twentieth century, as physicists tried to understand radium's properties, physicians used radium as an experimental therapy to treat a wide range of maladies, especially skin and gynecological cancers because of their accessibility to external treatment. Within two decades, as physical and clinical discoveries illuminated radium's capacities and made more effective therapies possible, radium therapists and radiation physicists brought radium into hospitals. This move allowed radium therapy to become more standardized, and the complex equipment needed to purify the radium emanation, a decay product of radium, used in new modes of therapy necessitated the employment of radiation physicists, who collaborated with radium therapists. This dissertation examines radium's early career as a therapeutic agent, focusing in particular on the new relationships forged between physicists and physicians in the first half of the twentieth century. These connections were critical in fostering and bounding the development of American radium therapy.

I identify two main periods of American radium therapy: the experimental period, 1900–1910, and the professionalizing period, from 1911 to around 1934. The first period is dominated by the influences of the American radium craze, an upswell of public interest in the new element and its potential applications. A few interested physicians accessed physics networks to acquire and use radium in the treatment of a variety of diseases, though cancer emerged as an area of particular interest because of radium's ability to shrink many tumors that were beyond the aid of surgery. At the beginning of the 1910s, American industrialists established radium processing plants, mainly for the production of radium for medical use, and the federal government considered nationalizing medical radium supplies. In the second period, radium therapy gained greater acceptance from the medical community and moved out of individual physicians' offices and into hospitals, becoming a hospital-based therapy.

The American public's fascination with radium and the public's hope for its medical efficacy led many physicians and physicists to speculate on or experiment with radium, and their findings in turn stoked popular excitement. Using the lectures of leading American popularizer of radium William Hammer as its lens, the first chapter explores the interplay between popular perceptions and professional interest at the height of the radium craze that gripped America in the first decade of the twentieth century. This chapter provides important context for the public understandings of radium therapy and sets the stage for the following chapters. Hammer lectured to a wide variety of audiences, demonstrating his glowing tubes of radium, and emphasizing its expense, scientific novelty, and potential applications.[1] Americans dreamed of radium, "the modern miracle," lighting their homes and wiping out cancer. In this chapter I argue that the radium craze was emblematic of popular optimism in science and made the establishment of American radium therapy possible by sparking the interest of many physicians.

The period from 1900 to 1910 is the first, experimental period of American radium therapy, and is analyzed in chapter two. This period is defined by the influences of the radium craze and the disparate research and clinical methodologies which were being tried by early adopters of radium therapy. Therapy was largely empirical, based on clinical observations, and there were no standards for dosage. However, physics knowledge provided important guidelines for clinical methodology—the understanding that the radiation from radium salts were composed of three kinds of rays, for example, led physicians to select those they found efficacious by using filtration. Additionally, physicians needed to connect with radioactivity research networks to acquire radium that they could use in their practice. This chapter argues for the centrality of these connections and for the boundaries physics knowledge placed on informed clinical experimentation.

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[1] The price of radium fluctuated widely, based on changes in supply and increases in demand, but the cost of a gram of radium was always five digits.

Chapter three examines the ways in which radium therapists acquired and exchanged physics knowledge about radium's properties and used this knowledge to develop appropriate and safe methods, dosages, and filtration techniques. In the first decade of the twentieth century, American physicians wanting to use radium could turn to the radium therapy chapters of a handful of texts focusing on physical therapies to supplement the thin American medical literature on the subject. By the 1910s, American physicians and physicists began to produce their own texts for training. Based on the analysis of several American radium therapy textbooks, the third chapter demonstrates that clinical experience and knowledge of the physics of radium were the essential combination required for effective treatment. These texts urged physicians wanting to use radium to have access to good physics texts or a university physics professor, if not both, to ensure efficient, safe, and effective treatments. In this way, I argue, the development of radium therapy by specialist physicians was dependent upon information from, and communication with, physicists.

The second period of American radium therapy, from 1911 to around 1934, as argued in the fourth chapter, was characterized by professionalizing efforts of radium therapists and radium's move from private practices to hospitals. The introduction of radium emanation plants, which collected gaseous radium emanation for therapeutic use, was crucial for this move. These plants originated in physics laboratories and were adapted by physicist William Duane for clinical use. Radium emanation provided greater therapeutic flexibility than radium salts. These plants required large amounts of radium and space, which put them out of the reach of most individual physicians. Emanation plants also necessitated the oversight of a physicist, and consequently this period saw the hiring of the first hospital physicists, who collaborated with physicians in the treatment of patients. In this second period, physicists and physics knowledge were of even greater importance to radium therapy.

The Beginnings of Radium Therapy

At the turn of the twentieth century, radioactivity seemed to have much in common with X-rays, and scientific and medical researchers wondered if radium might find clinical utility, similar to X-rays. The first report on the biological effect of radium was by German dentist Otto Walkhoff in 1900. He had also been interested in medical applications of X-rays. He obtained a radium preparation from chemist Friedrich Giesel to see what the effect of radioactivity was on living tissue; after two twenty-minute exposures, his arm became inflamed in a reaction similar to overexposure to X-rays.[2] Giesel also repeated Walkhoff's experiment and confirmed his results. Walkhoff published his results in *Photographische Rundschau*, a photography journal, which explains why his experiment is not well known.[3] The next year, in a more well-known incident, Henri Becquerel accidentally burned himself with a vial of radium in his vest

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[2] Giesel both purified and researched radioactive materials, and in the early 1900s was a unique source of strongly radioactive materials, as the Curies only provided moderately active sources. Lawrence Badash, ed., *Rutherford and Boltwood: Letters on Radioactivity* (New Haven and London: Yale University Press, 1969), 83.

[3] John Harley Warner, "Recognition of the Biological Action of Radium Radiation," *Journal of Chemical Education* 53 (1976), 579.

pocket, which inspired Pierre Curie to intentionally burn his arm.[4] Becquerel showed his burn to a dermatologist, who suggested that radium might be used therapeutically, and the Curies gave some radium to dermatologist Henri-Alexandre Danlos at Paris's *Hôpital St. Louis*, who used it to treat skin conditions such as lupus.[5] Radium was soon used on patients with diseases such as keloids, tuberculosis, syphilitic ulcers, and hyperthyroidism. Skin cancers and gynecological cancers were also treated, as the tumors were accessible by external applications of radium. [6]

Radium therapy was, in the terminology of the time, a physical therapy, a therapy based on physics. Other main physical therapies at the beginning of the twentieth century were electrotherapy and roentgenology. Many early radium therapists had experience with other physical therapies, and understood it in the context of these (also comparatively new) modes of treatment. Having a scientific basis was a core part of the identity of these therapies, and physical therapists valued scientific knowledge.

The story of American radium therapy, while related to these other physical therapies, is distinct in how the field developed and how radium therapists interacted with physics and physicists. Roentgenologists, for example, fought to prove themselves as

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[4] See Badash, *Radioactivity in America*, 127. Curie also reported that in the course of their normal research with radioactive materials, both he and Marie suffered from painful inflammations in their hands. Warner, "Recognition of the Biological Action of Radium Radiation," 579.

[5] Badash, *Radioactivity in America*, 127; Harry H. Bowing and Robert E. Fricke, "Curie Therapy," in *The Science of Radiology,* Otto Glasser, ed. (Springfield, Illinois: Charles C. Thomas, 1933). The first recorded use of radium therapy was a patient treated for lupus by Danlos and Paul Bloch in 1901. R.F. Mould, "Priority for radium therapy of benign conditions and cancer," *Current Oncology* 14 No. 3 (June, 2007): 118-122.

[6] As a note on terminology, in this dissertation I will use the general term radium to refer both to the element and to salts of radium, which was the form in which the new element was overwhelmingly available to scientists and physicians. I use explicit terminology when the distinction is important and unclear from context.

legitimate medical—not technical—specialists. The large machines at the center of roentgenology also allowed scientists, engineers, and technicians to become some of the leading early contributors, a situation not found in radium therapy, which was based on small pinches of radium salt. Consequently, part of the professionalizing process for roentgenologists, but not radium therapists, was the exclusion of practitioners not trained in medical schools.[7]

American radium therapists collaborated with scientists studying radium. Throughout this dissertation, I refer to physicians employing radium as radium therapists. This is an actors' term: Isaac Levin self-identifies as a "radium therapeutist" in 1919, Henry Janeway refers to "the majority of radium therapeutists" in the same year, and the Radium Company of Colorado published a journal titled *The Radium Therapist* from 1922–1933.[8] American radium therapists collaborated with scientists studying radium and radioactivity, many of them physicists, which is generally the term I use to describe these scientists in the interest of brevity and maintaining a clear connection with the study of the physics of radioactivity. However, the study of radioactivity was in many ways situated between physics and chemistry, and leading the field at the beginning of the twentieth century were the physicist-chemist teams of Ernest Rutherford and Frederick Soddy and Pierre and Marie Curie. I refer to individuals as physicists or chemists as

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[7] This is the argument made by Bettyann Holtzmann Kevles in *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, New Jersey: Rutgers University Press, 1997).

[8] Martin Cohen and Isaac Levin, "The Action of Radium on Cataracts," *Journal of the American Medical Association* 73 (1919): 1199. (The statement was made by Levin in the discussion of their joint paper given at the 1919 AMA conference.) Henry H. Janeway, "The Treatment of Uterine Cancer by Radium," *Radium* 4 No. 2 (November, 1919): 17–51.

appropriate, but when discussing a general group predominantly composed of physicists, I label it as a group of physicists.

To get an idea of the character of American radium therapy at the beginning of the twentieth century, it is worth looking at data collected in two texts in the 1920s: the *Bibliography on Radium* and the *Compendium of Abstracts of Papers on the Therapeutic Use of Radium*, published by the United States Radium Corporation and the Radium Chemical Company, respectively.[9] The *Bibliography* aimed to be as comprehensive as possible and included thousands of references from medical journals; in the data I present below I only include articles from American authors in domestic journals and exclude the significant European literature. In Figs. 0.1 and 0.2 below, the domestic citations collected in the *Bibliography* are arranged by year of publication and by their subject (as sorted in the text). Fig. 0.1 clearly shows a spike in medical interest in radium corresponding to the American radium craze, and a dip in publications the year after the end of World War I. Fig 0.2 demonstrates the range of medical interest in the physics of radium and the predominant focus on using radium to treat cancers, particularly those of the skin and accessible body cavities. The *Compendium* was more modest in scope, including only 139 American papers from 108 authors, but the significant interest in cancer is clear from these references, as is shown in Table 0.1.

[9] *Bibliography on Radium: Its Uses and Results from Its Discovery Up to January, 1922* (New York: United States Radium Corporation, 1922). The first and second supplements of the *Bibliography* bring its data through the end of 1923. *Compendium of Abstracts of Papers on the Therapeutic Use of Radium: With a Glossary of Terms in Radioactivity and Radiumtherapy* (Philadelphia: Radium Chemical Company, 1920).

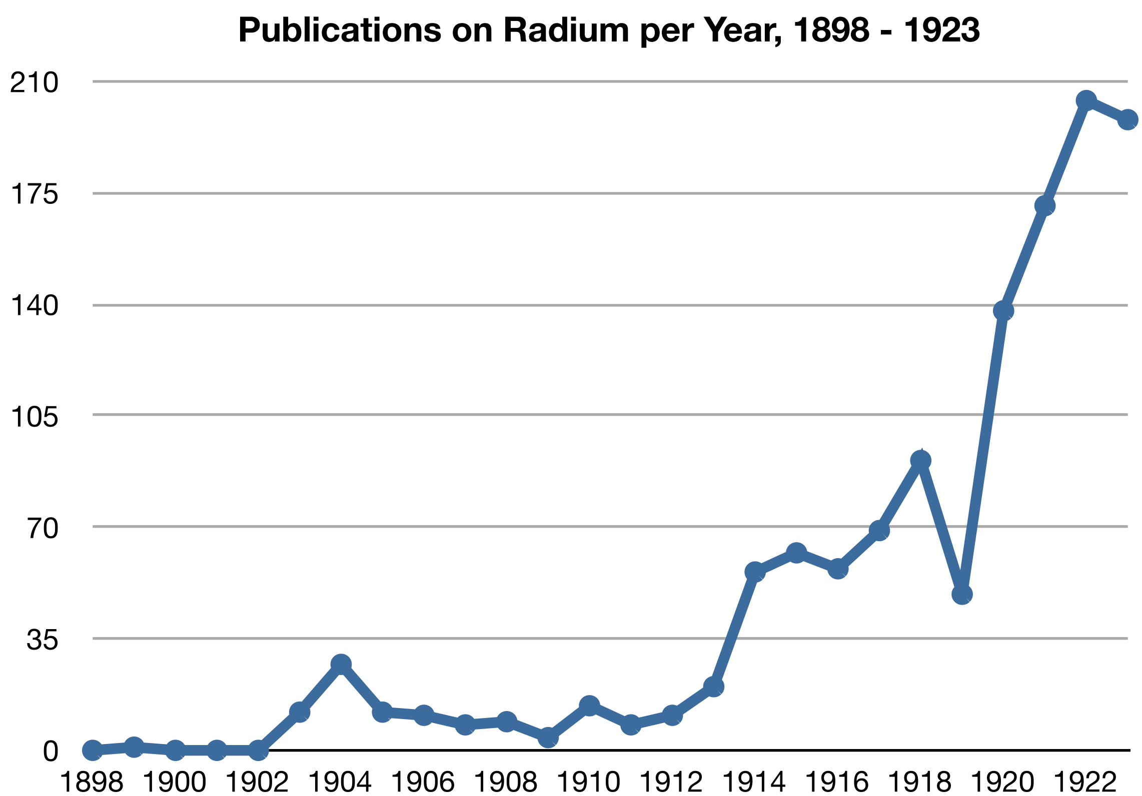

Figure 0.1. Data from *Bibliography on Radium*, limited to American authors and journals.

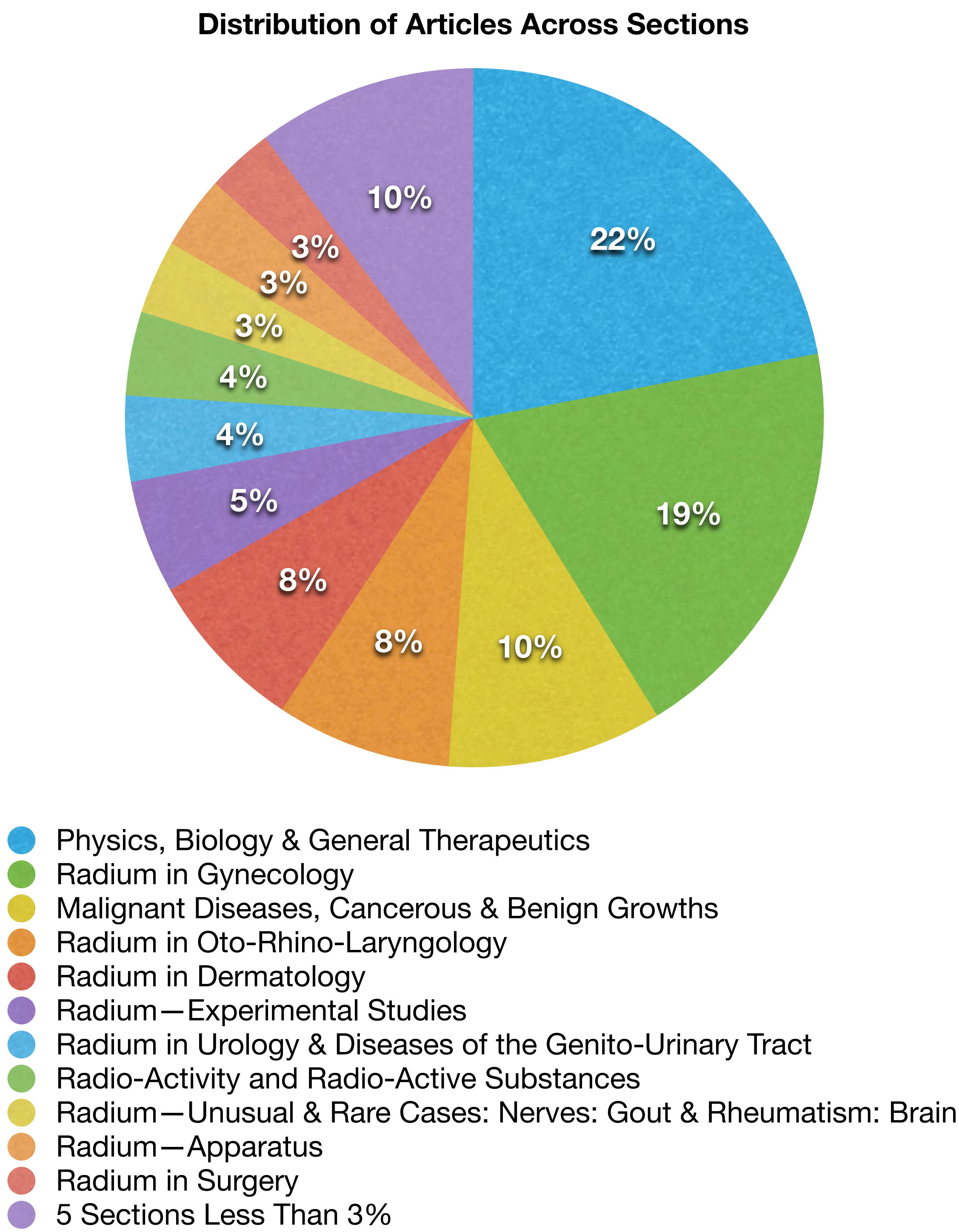

Figure 0.2. The *Bibliography on Radium* identified several general sections of medical articles. Listed above, in descending order of frequency, are the main categories of American radium therapy articles published from 1898–1922.

Most General Category	# of Articles	% of articles
Cancers & Malignancies	85	61.15
Non-Malignant Diseases	56	40.29
Technique	13	9.35

Table 0.1. Author-identified general categories of the articles included in the *Compendium of Abstracts of Papers on the Therapeutic Use of Radium*.

Historiographical Connections

This study of American radium therapy, and the role of physics and physicists in it, is motivated by a few key research questions. How did radium therapy fit into the broader medical marketplace? How did the popular fervor over radium as a wonder drug transition into the new element becoming an accepted facet of scientific, hospital-based cancer treatment? How did physicists and physics knowledge impact radium therapists and shape the course of their practice? An important first step in addressing these questions is situating them against similar ones in the historiography.

The history of radioactivity and its medical uses intersects with several areas within the history of science and history of medicine literature. Historians of medicine have studied scientific medicine, the history of cancer, and the varied medical marketplace at the beginning of the twentieth century; and all are relevant areas to the history of radium therapy. Historians of science have studied the development of the science of radioactivity and the public understanding of radiation. One of the aims of this project is to bring these historians into communication with each other. There are a handful of studies focusing on radiation therapies, but these generally focus on physicians. Radium therapy involved both physicians and physicists, and this history of radium therapy, which focuses on the interactions and relationships between physicians and physicists in the practice of radium therapy, therefore bridges the history of medicine and the history of science.

Radium therapy has a close association with the emergence of scientific medicine or laboratory medicine (as it is more accurately termed) in American hospitals around the turn of the twentieth century. In the period from the 1870s to the 1920s, hospitals went from being places largely for the poor and chronically ill to scientifically managed centers visited by patients from all social classes. This change had much to do with the growth of American cities but was greatly aided by developments in medical science and technology.[10] Charles Rosenberg identifies the "x-ray, antiseptic surgery, and clinical laboratories," as hallmarks of scientific medicine.[11] Physicians brought X-rays into hospitals soon after their discovery in 1895 by Wilhelm Röntgen; in the 1880s, antiseptic surgery made surgical procedures far safer and successful, especially abdominal and gynecological surgeries; and laboratories for clinical pathology, which led to improved diagnosis, were introduced at around the same time. Joel Howell has argued that the hospitals of this period became increasingly technological, and that scientific

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[10] Rosemary Stevens, *American Medicine and the Public Interest* (Berkeley: University of California Press, 1998), 34.

[11] Charles E. Rosenberg, *The Care of Strangers: The Rise of America's Hospital System* (New York: Basic Books., Inc., 1987), 237.

management extended to the ways that hospitals' administrations were organized.[12] Surgeons especially seemed to benefit from scientific medicine in American hospitals: in addition to antiseptic surgery, the central organization often prioritized surgery, and surgeons' efficacy and power and increased.

The promise of safe and effective surgery was instrumental in the transformation of hospitals, in the first few decades of the new century, from centers for charitable treatment to places where paying patients were comfortable seeking treatment. Because surgery was the primary means by which hospitals attracted paying patients in this period, surgeons enjoyed positions of power within hospitals. There was also a push for reform in medical education around the turn of the century, highlighted by the 1910 Flexner report, which made public an established internal debate about reform and recommended changes to both teaching and research. The main effect of education reform was increased standardization of medical education. There was an increasingly middle-class group of medical school graduates who, by the 1930s, were inclined to be medical specialists rather than general practitioners.[13] In *Learning to Heal*, Kenneth Ludmerer argues that by the early 1900s, reformed medical education was characterized by full-time professors and a teaching emphasis on practical clinical concerns and the laboratory sciences.[14] This emphasis on science, as Paul Starr argues in *The Social Transformation of American Medicine*, helped identify physicians with science in the

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[12] Joel D. Howell, *Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century* (Baltimore: Johns Hopkins Press, 1996).

[13] See Rosenberg, *The Care of Strangers*, 209, and Stevens, *American Medicine and the Public Interest*, 67.

[14] Kenneth M. Ludmerer, *Learning to Heal: The Development of American Medical Education* (Baltimore: The Johns Hopkins University Press, 1985).

public mind, and this association benefited physicians as science gained public respect at the beginning of the century.[15]

World War I's army hospitals were in part modeled on modern, scientific hospitals, were highly reliant on laboratory medicine, and their efficacy, especially in the treatment of infectious disease, in turn increased the influence laboratory medicine had on hospitals after the war. In *Technology and the Hospital*, Joel Howell argues that "the entire hospital had become, by 1925, quite actively and self-consciously based on science."[16] X-ray machines, for example, were at least as important to hospitals as symbols of scientific medicine than as diagnostic devices. Because of radium's birth in the laboratory and its close association with cutting-edge scientific research, radium therapy was another scientific therapy, adding to practitioners' clinical armamentaria and their claims to authority.

Radium therapy does not play a large role in most histories of cancer. Radium therapy was closely identified with cancer, but in the first decades of the twentieth century surgery remained the medical profession's preferred method for combating cancer. In *The Dread Disease*, James Patterson identifies periods of excitement about radium therapy in 1913 and in 1921 after Curie's visit to the United States, but this excitement did not make radium therapy more popular than surgery.[17] Surgery was the primary mode of cancer therapy at the beginning of the twentieth century, strongly

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[15] Paul Starr, *The Social Transformation of American Medicine: The Rise of a Sovereign Profession and the Making of a Vast Industry* (New York: Basic Books, Inc., 1982).

[16] Howell, *Technology in the Hospital*.

[17] James T. Patterson, *The Dread Disease: Cancer and Modern American Culture* (Cambridge, Massachusetts: Harvard University Press, 1987), 65.

influenced by William Halstead's work with radical mastectomies, as studied by Barron Lerner in *The Breast Cancer Wars* and Robert Aronowitz in *Unnatural History*.[18] John Pickstone argues that unlike many European cancer clinics and institutes, which were centered on pathology or biophysics, American cancer hospitals were generally led by surgeons.[19] Radium therapy, then, posed a potential economic and professional threat to the dominance of surgery, and thus to surgeons. Many physicians hoped that the less frightening alternative of radium therapy would encourage patients to seek treatment rather than avoiding doctors for fear of surgery. This project draws upon this strong existing historiography of cancer, and enriches it by highlighting the understudied area of radium therapy.

Like X-rays, radium was popular with the general public. Part of this enthusiasm was expressed in the wide variety of patent medicines and other home cures available that boasted the use of radium. In *Negotiating Disease*, Barbara Clow argues that many patients feared cancer, were generally trusting of physicians but also often relied on alternative medicines.[20] Patent medicines claiming to include radium appeared, and, early on, were sometimes incorporated into clinical therapy, as in the case of radium water. James Harvey Young's *The Medical Messiahs* gives an excellent overview of

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[18] Barron H. Lerner, *The Breast Cancer Wars: Hope, Fear, and the Pursuit of a Cure in Twentieth Century America* (Oxford: Oxford University Press, 2001). Robert A. Aronowitz, *Unnatural History: Breast Cancer and American Society* (Cambridge: Cambridge University Press, 2007).

[19] John V. Pickstone, "Contested Cumulations: Configurations of Cancer Treatments through the Twentieth Century," *Bulletin of the History of Medicine* 81 (Spring, 2007), 169.

[20] Barbara Clow, *Negotiating Disease: Power and Cancer Care, 1900-1950* (Montreal & Kingston: McGill-Queen's University Press, 2001). Patent medicines and other alternative medicines involving radium are the focus of Robert Holmes, *Substance of the Sun: The Cultural History of Radium Medicines in America* (PhD dissertation, University of Texas-Austion, 2010).

quack cures in twentieth-century America.[21] Sellers of patent medicines capitalized on the popularity of and public faith in science, using the rhetoric of science—the same rhetoric which supported the popularity of X-rays and radium—to market their drugs. By the 1920s, Young demonstrates, quack cure-alls were challenged by pressure from the Federal Trade Commission, the American Medical Association, the National Better Business Bureau, and the Food, Drug and Insecticide Administration (the precursor to the FDA, created in 1927) to rein in the exaggerated, misleading and false advertising claims that were characteristic of patent medicines.[22] Claudia Clark demonstrates how the famous scandal, starting in 1922, over the poisoning of radium dial painters contributed to the removal of radium-containing patent medicines from the marketplace.[23] After 1925, Clark argues, treatments involving ingesting radium were denounced by physicians, though they persisted a little while longer in medicines peddled by quacks.[24] Before the 1920s, though, there was a wide variety of medicines claiming to contain radium available to consumers.[25]

World War II was a significant turning point in popular opinions on radiation, and it has also shaped the traditional historiographical narratives of radiation, which focus

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[21] James Harvey Young, *The Medical Messiahs: A Social History of Quackery in Twentieth-Century America* (Princeton: Princeton University Press, 1967).

[22] Ibid., 147.

[23] Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910-1935* (Chapel HIll: The University of North Carolina Press, 1997).

[24] Ibid., 172.

[25] As an example of the relative lack of concern over the dangers of radioactivity, when the AMA set standards on radium content in patent medicines in 1914, these standards set out the "*minimum* strength" of radium solutions to prevent the sale of medicines falsely claiming to contain radium. Ibid., 56.

mainly on the post-war Atomic Age. The recent scholarship of Angela Creager and Maria Rentetzi is opening up other aspects of radiation therapy by illuminating connections between physics and medicine and by connecting the post-war period with the beginnings of the century. The interactions between physicians and physicists are important to Creager's research, but her analysis focuses on the post-war period. By documenting the importance of the relationships between physicists and physicians before 1945, my project reveals the precedents involved in this post-war success. In "Nuclear Energy in the Service of Biomedicine," Creager argues that the Atomic Energy Commission used the Oak Ridge isotope program, which supplied radioisotopes for medical use, to promote the image of nuclear energy as a peaceful, civilian resource.[26] The Joliot-Curie's 1934 discovery of artificial radioactivity allowed the production of artificial radioisotopes, radioactive isotopes produced in the laboratory. A few American physicians gained access to artificial radioisotopes and began experimental cancer therapy in pre-war years, most notably Ernest Lawrence's brother John Lawrence.[27] It was not until after the Second World War, with Big Science reactors and cyclotrons producing radioisotopes, that they began to replace radium in American hospitals. Radioisotopes eventually replaced radium in radiation therapy. Radioisotopes generally have shorter half-lives, making them safer and easier to control, and they can be used to directly target specific

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[26] Angela N.H. Creager, "Nuclear Energy in the Service of Biomedicine: The U.S. Atomic Energy Commission's Radioisotope Program, 1946-1950," *Journal of the History of Biology* 39 No. 4 (Winter, 2006): 649-684.

[27] On the Lawrences, see J. L. Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory* (Berkeley: University of California Press, 1989). There were also interwar medical studies of radioisotopes at MIT and the University of Rochester; George L. Voelz and Donald Petersen, as told to Debra A. Daugherty, "Tracer Studies at Los Alamos and the Birth of Nulcear Medicine," *Los Alamos Science* 23 (1995): 256-279.

organs for therapy or diagnosis by taking advantage of the body's biochemistry since the body treats them exactly the same way as their non-radioactive counterparts—two large advantages over radium. With this context, this dissertation extends the analysis of physician-physicist exchanges into the pre-1945 era.

Rentetzi studies the cultural and material contexts of radium research, and I draw on her concept of radium as a "trafficking material," an object that gains meaning through exchange, in my analysis of the relationships between physicists and physicians. In "The U.S. Radium Industry," she argues that in the absence of strong academic leaders in American radium research, the American radium industry shaped research. [28] She suggests the zeal of industrial researchers for promoting their company led them to overlook health concerns for some sorts of radium treatment, for example, initially interpreting the absorption of radium (chemically similar to calcium) into bone as a positive result.[29] In Europe, she argues, research was led by academia rather than industry. Consequently, the character of American research was more practical and focused on expanding the boundaries of radium therapy in the hopes of expanding the market. In addition to these differences illuminated by Rentetzi, the differences between the medical marketplaces in Europe and America make American radium therapy distinct., and these distinctions helps to motivate this dissertation's focus on America.

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[28] Maria Rentetzi, "The U.S. Radium Industry: Industrial In-house Research and the Commercialization of Science," *Minerva* 46 (2008): 437-462.

[29] For an example of the advertising the Standard Chemical Company would use, see "Standard Radium Solution for Drinking (ca. 1915 - 1920)," Oak Ridge Associated Universities Health Physics Historical Instrumentation Collection: http://www.orau.org/ptp/collection/quackcures/standradiumsolution.htm .

The cultural understanding of radioactivity is an important part of the backdrop of this study. The American public was fascinated with radium and radioactivity, a fascination which shaped the views of radium therapists and their patients. Spencer Weart looks at the rhetoric and imagery surrounding radioactivity in *Nuclear Fear* and finds connections between the new modern science and ancient ideas of death rays and magic.[30] These symbols and images are particularly apparent in the American radium craze, which was a catalytic event in the development of American radium therapy. Lawrence Badash's *Radioactivity in America* analyzes both the popular excitement over radioactivity and the scientific and medical research and applications of radium. He also traces how the story of radium in America involves industry. In response to the limited supplies of radium in the 1910s and the high cost of importing radium purified in Germany or France, American companies became involved in purifying domestic radium-bearing ores. By the mid-1920s, there was more radium produced in America than in the rest of the world combined.[31] Badash argues that radium therapy began to fall out of favor at the end of the 1930s in the face of improved X-ray machines, neutron therapy, and artificial radiation.[32] In *The First Atomic Age: Scientists, Radiations, and the American Public, 1895–1945,* Matthew Lavine analyzes the cultural background and

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[30] Spencer R. Weart, *Nuclear Fear: A History of Images* (Cambridge: Harvard University Press, 1988).

[31] Badash, *Radioactivity in America*, 149. American industry quickly lost interest in maintaining domestic sources of purified radium, however, after large deposits of radium-containing ore were discovered and made available in the Belgian Congo in 1922. This ore could be mined, purified, and imported much more cheaply than European radium. The development of the American radium industry is analyzed in Edward R. Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," *Colorado School of Mines Quarterly* 82 No. 2 (Summer, 1987).

[32] Ibid., 150.

influences of radium and X-rays and draws out the tensions between experiencing radiation through popular media and experiencing it in person at demonstrations or in the clinic.[33] He argues that the public's enduring fascination with radioactivity and X-rays was bolstered by their mysteries and existence outside the range of everyday experiences. While the existing literature has prioritized the Atomic Age, in this project I, like Lavine, focus on the decades before World War II: a period when physicians and physicists worked together, on an experimental new therapy that transitioned from private practices to becoming an important part of hospital's scientific identities.

The culture of the science of radioactivity is also relevant to this work. Radioactivity was a new field of scientific inquiry, and involved new collaborations and new methods of investigation. Jeffrey Hughes illuminates the international community of radioactivity researchers in his dissertation, *The Radioactivists*.[34] He argues that "a very specific social, material and intellectual culture" shaped the development of nuclear physics. He demonstrates, for example, how the late 1920s Cambridge-Vienna controversy over methodology and the structure of the nucleus led to a competitive culture fostering the development of new research centers.[35] This research culture that Hughes identifies is an important part of the context for this project, since the physicists who collaborated with radium therapists worked within it. *The Rays*, by Ruth Brecher and Edward Brecher, is another key text of the radioactivity historiography, and focuses

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33 Matthe Lavine, *The First Atomic Age: Scientists, Radiations, and the American Public, 1895–1945* (New York: Palgrave Macmillan, 2013).

34 Jeffrey Hughes, *The Radioactivists: Community, Controversy, and the Rise of Nuclear Physics* (PhD thesis, University of Cambridge, July 1993).

35 Ibid., 287.

specifically on radiology and radium therapy.[36] They focus on the first half of the twentieth century and investigate the major developments in methodology and professionalization, providing an important backdrop for this dissertation.

Radium therapy was, of course, not just an American phenomenon. Two scholars have focused specifically on radium therapy, and study it in Britain and in Canada. Their work provides essential context for this dissertation by illuminating the development of radium therapy in these countries. While similar in many ways, there are important differences which will be drawn out in this work. In *Deadly Sunshine*, David Harvie concentrates on British radium therapy. Written for "the possibly mythical beast, 'the informed general reader,'" Harvie looks at the misuses of radium over the course of the twentieth century, which includes an analysis of the British sites that are still contaminated as a result of a historical involvement with radium.[37] As was the case in America, many large British hospitals were interested in trying radium therapy in 1910s, but had difficulty in obtaining a large enough supply of radium. Though Harvie's work has a different focus than my project, his analysis of British radium therapy provides an essential example of radium therapy in the Atlantic world. Charles Hayter also studies radium therapy, focusing on Canada, in *An Element of Hope*. He demonstrates how radium was a "glamorous symbol of the new 'scientific' medicine," and argues how the eventual government involvement was crucial to widespread Canadian use of radium

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[36] Ruth Brecher and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: The Williams and Wilkins Company, 1969).

[37] David Harvie, *Deadly Sunshine: The History and Fatal Legacy of Radium* (Stroud, Gloucestershire: Tempus Publishing Limited, 2005), 13.

therapy.[38] In "The Clinic as Laboratory," Hayter emphasizes the empiricism of radium therapy.[39] He argues that knowledge about radium therapy came from the clinic, not the laboratory; belief in the effectiveness of radium therapy was therefore based on experience more than experiment. In this project, I challenge this analysis by arguing that knowledge about radium therapy was *also* informed by laboratory discoveries—the empiricism of radium therapy, especially in the first decade of the twentieth century, is clear but as I argue it was informed and bounded by knowledge created in the physics laboratory. Hayter and Harvie's work illuminate the development of radium therapy in Britain and Canada, and this dissertation expands the picture of radium therapy in the early twentieth century by providing a focus on America and on the relationships between physicists and physicians.

The current radium therapy historiography generally prioritizes the role of physicians. The exchange between physicians and physicists has a central role in this dissertation. This is all the more significant because while historians of medicine have long recognized the importance of the relationships between biomedical scientists and physicians in twentieth century medicine, the role of physicists in this history is not well recognized or understood. My project advances the historiography by revealing the centrality of physician-physicist collaborative relationships, even interdependence, in the early history of radium therapy.

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[38] Charles Hayer, *An Element of Hope: Radium and the Response to Cancer in Canada, 1900-1940* (Montreal & Kingston: McGill-Queen's University, 2005), 53.

[39] Charles Hayter, "The Clinic as Laboratory: The Case of Radiation Therapy, 1896-1920," *The Bulletin of the History of Medicine* 72 No. 4 (1998): 663-688.

Chapter One

The American Radium Craze

Introduction

A visitor to William Hammer's midtown Manhattan apartment in 1903 would be confronted with startling wonders. If arriving after dark, the front door's keyhole would be glowing greenly. Hammer, a popular lecturer on radium, would explain that when in Paris the year before, he had obtained a small amount of radium, and then had carefully used a tiny bit of this to make paint which, like radium, glowed of its own accord. Unlike phosphorescent substances, radium did not need to be initially exposed to a light source, nor did it ever seem to run out of energy. Hammer might then show his visitor the other things he had painted: the mouthpiece of his telephone, a clock, the labels to bottles of poison, all glowing helpfully in the dark. Less practical, but no less wonderful, were the radiumized buttons, pins, figurine, artificial flowers, and small toys with which Hammer's young daughter might have played.[40] An interested visitor might then be shown to Hammer's home laboratory, filled floor-to-ceiling with glassware, tools,

[40] William Hammer, "Radium and Other Radioactive Substances with a Consideration of Phosphorescent and Fluorescent Substances," *Transactions of the American Institute of Electrical Engineers* XX No. 5 (May, 1903): 541–613; notes on Hotel Earle stationery, Series 1, Box 2, folder 6, William J. Hammer Collection of the Archives of the National Museum of American History (hereafter denoted as WHC). Hammer made the paint with radium, zinc sulfide, and dammar gum. He decided not to patent his formulation since radium was such a scarce commodity and so few people had access to it late in 1902, when he created it. June 5, 1926 memorandum, Series 1, Box 17, folder 8, WHC.

experiments-in-progress—and his precious collection of radium, carefully swaddled in cotton and stored in small wooden boxes.[41]

William Hammer was one of only a very few Americans, likely less than a dozen, who owned radium salts at the time. A consulting electrical engineer who had previously worked with Thomas Edison, mainly in lighting, Hammer had wide-ranging interests in science and engineering. It was his interest in luminescence and phosphorescence that led him to an interest in radioactivity and radium. He soon began giving popular lectures on those topics, and became the most influential popularizer of radium in America.

Radium had been discovered in 1898, but it wasn't until 1903, when our imaginary visitor gaped at the radium in Hammer's home, that the United States public began to pay significant attention to it. Ernest Rutherford's and Frederick Soddy's 1901 discovery of nuclear transmutation, that radioactive elements change into new elements in the process of decay, added to radium's visibility, as did the 1903 discovery by the Curies that radium is continually producing heat. The 1903 Nobel Prize in Physics was awarded to Marie and Pierre Curie and Henri Becquerel, which also spurred popular attention to the element they had discovered. Radium became enormously popular, seemingly overnight; articles about it flooded the newspapers and magazines, with stories about its novel properties, its unprecedented price, and possible applications. The press

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[41] Hammer also obtained two samples of polonium in Paris, perhaps the only in America. His seven samples of radium ranged in activity from 40 to 70,000 times that of uranium. A photograph of Hammer's home laboratory appeared in "Remarkable Tests With Radium In Treating Diseases, Made by One of Newark's Own Sons, Now Engages Scientists," *Newark Sunday News* January 17, 1904. Hammer would carry his boxed radium to speaking engagements in a battered old valise. "Powers of Radium," *Duluth Evening Herald* Friday March 4, 1904. Any periodicals referenced in this chapter whose historical issues have not been digitized, such as these, were accessed in the WHC.

was quick to label this fascination a "radium craze."[42] Marked by widespread popular interest on a scale which had scarcely been reached by a scientific discovery, the American radium craze lasted roughly from 1903 to 1907. While these years marked the height of American interest in radium, this interest by no means died away quickly.[43]

Radium was so popular that it was displayed by the United States Geological Survey at the 1904 St. Louis World's Fair, with two lectures given on it each day. This was easily one of the most popular attractions at the exhibition.[44] Hammer collected news articles on radioactivity and headed his scrapbook of these from 1904: "YEAR OF EXTREME RADIOACTIVITY."[45] Scientific interest in radioactivity, like American popular interest, also exploded in 1903: a review of the scientific literature by Max Iklé has fewer than 50 papers on radioactivity in 1896, around 100 each in 1900, 1901, and 1902, but then nearly 250 in 1903.[46] In 1903, physician Samuel Tracy neatly summed up some of the main reasons that radium fascinated the public and professionals alike.

> 1. The discovery of radium may make it necessary to change our theories of the old hypothesis about matter and the conservation of energy.
> 2. Radium may possibly open up the way for a cheaper and more wholesome lighting of houses by phosphorescence.
> 3. Radium is a practical agent to differentiate genuine gems from artificial.

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[42] See, for example, "And Now the Radium Craze," *Wichita Eagle*, October 11, 1903.

[43] Carolyn Thomas de la Peña and Matthew Lavine both identify 1907 as an approximate transition point. Carolyn Thomas de la Peña, *The Body Electric: How Strange Machines Built the Modern American* (New York: New York University Press, 2003). Matthew Lavine, *The First Atomic Age: Scientists, Radiations, and the American Public, 1895–1945* (New York: Palgrave Macmillan, 2013).

[44] Lawrence Badash states that "the lectures and the exhibit of radioactive preparations and minerals were considered the outstanding attractions of the fair." Lawrence Badash, *Radioactivity in America: Growth and Decay of a Science* (Baltimore: Johns Hopkins University Press, 1979): 28.

[45] WHC.

[46] Cited in Bruce R. Wheaton, *The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism* (Cambridge: Cambridge University Press, 1991): 52.

> 4. Radium is a useful agent to kill bacteria.
> 5. Radium may be considered a valuable agent for the treatment of lupus, cancer, tuberculosis; and a possible agent to improve the eyesight and overcome partial blindness.[47]

Tracy's list emphasizes applications of radium, including medical ones, and is useful to consider as these applications are the focus of this dissertation.

William Hammer's numerous lectures across the country and popular book made him a leading American public intellectual on radium and radioactivity. His experiences with radium provide us an excellent window into the American radium craze. Radium's implications for science, its novelty and expense, and its wide-ranging possible applications formed the core of its popular fascination. The public and experts alike were generally willing to believe the best about radium, optimistically focusing much less attention on its dangers than on its scientific, industrial, social, commercial, and medical promises.

This chapter investigates the American radium craze and its implications for the beginnings of radium therapy, using William Hammer's lectures, experiences, and notes as a focal point. The chapter starts with an analysis of how Hammer was able to use his connections with the Curies and other leading scientists, and his possession of radium salts, to claim authority as a public intellectual. The next section is a close examination of his popular lectures, which demonstrate the current scientific understanding of radium and radioactivity and the great popular interest in radium's energy and its medical potential. The final section draws mainly from newspaper articles collected by Hammer, investigating how radium was presented in the press at the height of the radium craze,

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[47] Samuel G. Tracy, "Radium in Medicine," reprinted from the *New York Medical Journal and Philadelphia Medical Journal, Consolidated*, October 24, 1903. Tracy was advised by Hammer in writing this paper.

with subsections focusing on radium's price, its energy, and its promises for medicine. An analysis of a variety of newspaper articles illustrates that the high level of popular interest was largely expressed in optimistic imaginings of radium's possible applications. Throughout the chapter, we will see how the American radium craze was a time of great optimism and enthusiasm for the new element and its potential uses—and how this excitement spurred some to begin investigating its medical efficacy.

William Hammer as Public Intellectual

William Hammer lectured from a stage nearly overflowing with electrical apparatus, glassware, posters, and other objects for scientific demonstration, some of them faintly glowing green, apparently of their own accord (see Figs. 1.1–1.3). To the audience finding their seats at the beginning of the talk, he appeared a bearded figure in formal dress completely surrounded by boxes, tables, and cabinets. There were also phosphorescent paintings of stars, crosses, and grinning moons and skulls displayed about the stage.[48] The whole stage encouraged a sense of wonder, and promised that over the course of the evening, the audience would be let in on the secrets of nature.

The popular attention lavished on Röntgen's discovery of X-rays did much to set the stage for radium. X-rays' ability to make the invisible visible was fascinating, a bit frightening, and a completely unexpected shock to the Victorian world. Röntgen became famous almost overnight, and X-rays captured the public imagination, sparking a level of

[48] The skull imagery, also present in other popular illustrations related to radiation, was likely due to the close connections between X-rays and radium. The ability of X-rays to make the skeleton visible was one of the first things their discoverer, Wilhelm Roentgen, noticed about them and that image dominated the public conception of them.

attention and celebration never before lavished on a scientific discovery. Both X-rays and radium were new scientific discoveries in radiation, not fully understood even by their discoverers, and both held great promise for new therapies. Other new rays, like Finsen light and N-rays, also enjoyed the spotlight—but for none of these did the

Figure 1.1. This was a popular and often-reproduced portrait of William Hammer, figuratively throwing off rays much like radium. Hammer had this image displayed in his laboratory. WHC.

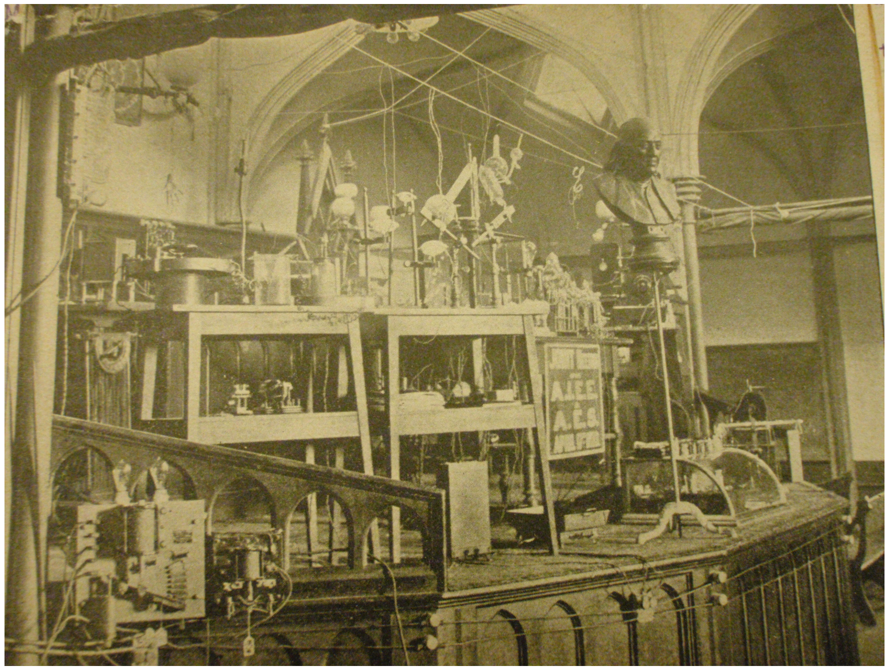

Figure 1.2. The stage setup for Hammer's 1903 lecture to the joint AIEE / AES meeting. WHC.

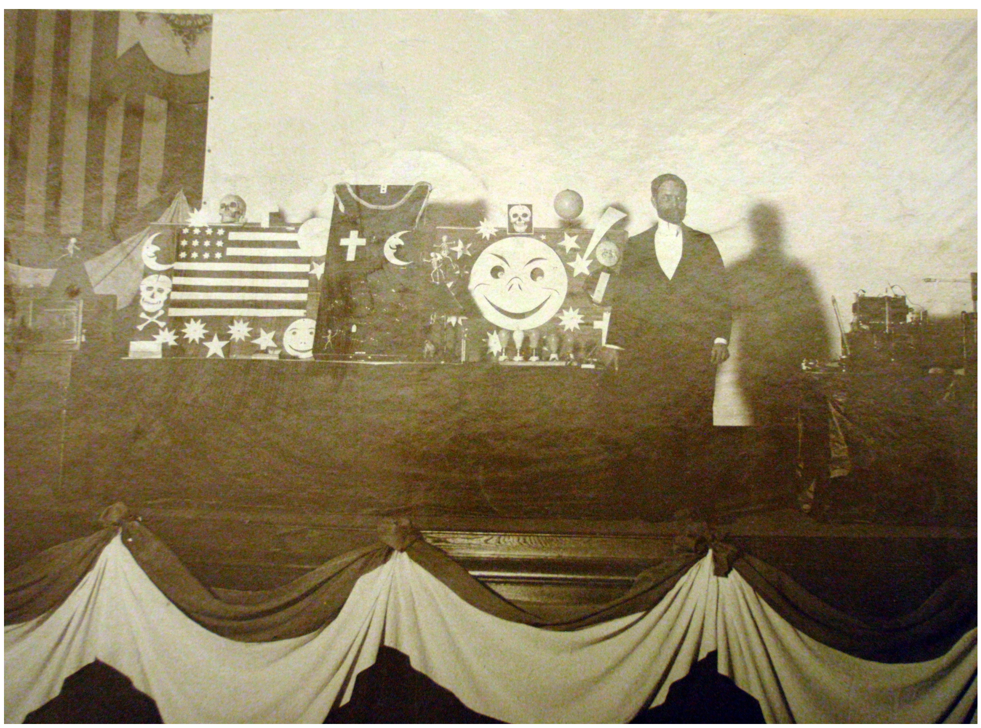

Figure 1.3. Hammer and part of his stage setup for an unknown lecture, ca. 1903. WHC.

spotlight shine as brightly and as for as long a time as for radium.[49]

Hammer's popular lectures were around an hour and a half long, and he remained on stage afterwards to answer any questions and to show samples and materials to anyone who wanted a closer look. He charged a speaking fee of between $75 and $200 for a lecture.[50] In 1903 he wrote that a recent lecture he gave in Pittsburgh filled the room with over 2,500 people, the largest crowd ever in that hall.[51] People were attracted to the chance to see radium in action, about which they read regularly in the newspapers.

Hammer gave at least ten popular lectures on radium in 1902, and in 1903 addressed a joint meeting of the American Institute of Electrical Engineers and the American Electrochemical Society (see Fig. 1.2). This lecture was based on his popular lectures, and he gave, by his count, at least eighty-eight similar lectures across the country between 1902 and 1926.[52] He addressed professional groups, schools,

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[49] N-rays were announced by Prosper-René Blondlot in 1903, named after his home of Nancy; they were soon shown to be fictitious. Finsen light was ultraviolet light developed for therapeutic use by Niels Finsen. Finsen received the Nobel Prize in Medicine and Physiology for this work in 1903, the same year that Becquerel and the Curies shared the Nobel Prize in Physics for the discovery of radium. Even compared with other radioactive elements, radium received the lion's share of press attention. Thorium was more readily available than radium, but its available salts were much less active; see, e.g., Willet L. Hardin, "Radioactivity," *Radium* 9 No. 2 (May 1917): 30–39. Radium's status as the most active radioactive element cemented its popularity even as the number of radioactive "elements" (many now understood as isotopes) climbed into the dozens. Thorium and polonium, especially, received some popular attention, but this attention paled in comparison to the gallons of ink spilt over radium. In the Curies' original fractionation, they obtained radium salts nine hundred times more active than uranium; and these salts were nearly an order of magnitude more active than the polonium they had already found. P. Curie, M. Curie, and G. Bémont, "Sur une nouvelle substance fortement radio-active, conenue dans la pechblende," *Comptes rendus de l'Académie des Sciences Paris* 127 (1898): 1215–1217.

[50] In some letters arranging his lecture fee, he would mention that Edison strongly encouraged him to lecture for no less than $300—and would then ask a much lower rate. For example, letter of November 12, 1903, Series 1, Box 3, folder 10, WHC.

[51] Letter of October 28, 1903 to James Beck, series 1, Box 3, folder 10, WHC.

[52] Memorandum of June 5, 1926, series 1, Box 17, Folder 8, WHC. Matthew Lavine counts at least fifty lectures by Hammer in 1903 and 1904. "A Cultural History of Radiation and Radioactivity in the United States," Wisconsin-Madison Ph.D. thesis: 178.

universities, and social organizations, from Massachusetts to Colorado. A book based on his lectures appeared in 1903, and was the first book in America on the subject. *Radium, and Other Radio-Active Substances* was aimed at a general audience.[53] Hammer also appeared often in newspapers, in reports of his lectures and in interviews. He had the ear of the nation.

Hammer was not the only American lecturer on radium. Many speakers made the circuit of schools and meeting halls giving scientific lectures, and at the height of the radium craze the new element would have been well represented in their topics. What set Hammer apart was his scientific knowledge and especially his possession of radium. I have found mention of one other lecturer who had a small sample of radium to demonstrate: the Rev. Dr. Charles H. Tyndall, whose themes and audiences were, on the whole, rather different from Hammer's.[54] Tyndall also had training in electrical engineering, but in his lectures in churches (as well as in schools and to social

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[53] William J. Hammer, *Radium, and Other Radio-Active Substances* (New York: D. Van Nostrand Company, 1903). The book sold for one dollar.

[54] The only evidence I have that Tyndall owned radium is a 1905 advertisement for his lectures, but it is possible that by that time he had purchased some very impure radium salts. 1905 advertising sheets, digitized by the Redpath Chautauqua Collection, University of Iowa Libraries Special Collections Department, accessed January 2012 at http://hdl.loc.gov/loc.award/iauchau./tyndall/1.

organizations) he emphasized "the wonderful forces of nature ... [and] the omnipotence and omnipresence of God."[55]

Though Hammer was trained as an electrical engineer, not as a physicist or chemist, his papers indicate that he kept up-to-date on the latest books and articles on radioactivity and radium. He corresponded with many of the leading physical scientists of the day; he wrote to Dayton Miller often for advice on problems in physics, and he also exchanged letters and preprints with men like Pierre Curie, Ernest Rutherford, and William Crookes.[56] Hammer was well-positioned to become the leading American public intellectual on the subject of radium.[57]

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[55] From a testimonial by Edgar T. Capel of the Sunday School Union, Province of Quebec, ibid. Ads for Tyndall's lectures in 1905 and 1910 make equally breathless claims: "He demonstrates ... how [radium] ... unlocks the secrets of creation; proves itself to be the 'missing link' in the chain of nature, and how it stands related to the profoundest as well as the simplest things of life." "Scientists" are quoted as describing radium as "'The most wonderful element ever discovered.' 'Nothing so marvelous in the history of the world.' 'The wizard element.' ... 'The key to most of the mysteries of nature.'" Ads for Charles H. Tyndall, ibid. Tyndall was not alone in seeing a connection between radium and religion, as we shall discuss briefly in chapter four. The language of Tyndall's advertisement seems hyperbolic in comparison to the matter-of-fact text in the advertisement for Hammer's lecture in Fig. 1.4.

[56] Dayton Miller is best known for his repetition of the Michelson-Morley experiment and his persistent belief in the ether; however this does not undermine his value to Hammer as an expert in physics.

[57] The leading scientific expert in America on radioactivity was chemist Bertram Boltwood, who did pioneering work with radioactive decay chains and radiometric dating. Boltwood's correspondence with Rutherford gives an illuminating view to his work in this area: Lawrence Badash, ed., *Rutherford and Boltwood: Letters on Radioactivity* (New Haven: Yale University Press, 1969). Though Boltwood illustrates that not all work on radioactivity occurred in Europe, as might be assumed, he will remain a comparatively minor figure in this story because of his limited involvement with radium popularization or therapy. Popularization of science around the turn of the century was largely the realm of scientists themselves; William Ramsay and Oliver Lodge were popular spokesmen for science during this time, but most of the leading lights in scientific research stayed out of the public realm. For discussions of how this scientist-lead popularization transitioned into a journalist/popularizer-led movement, see Peter Broks, *Understanding Popular Science* (New York: The McGraw-Hill Companies, 2006) and Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York: W. H. Freeman and Company, 1987).

How did Hammer claim legitimacy as an authority on radium to the American public? First and foremost, he stressed his trips to Europe and his connections with the leading European scientists involved with radium. His possession of radium, and his

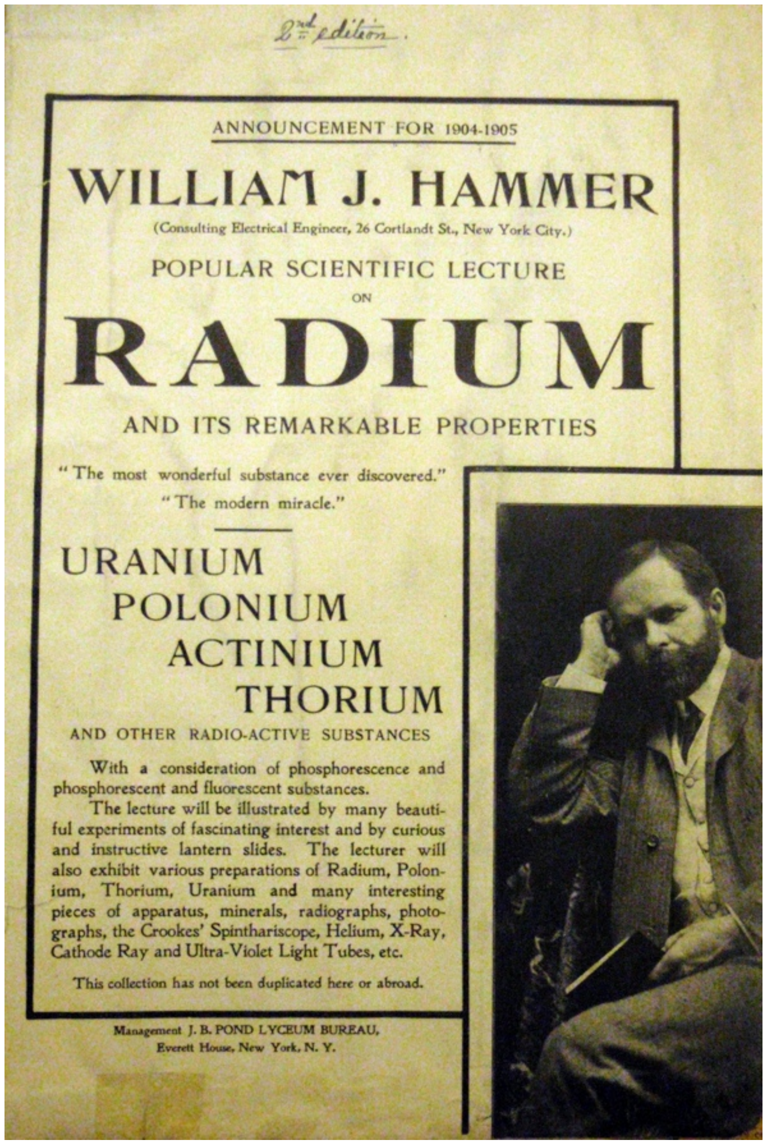

Figure 1.4. Advertisement for Hammer's popular lectures, quoting his pronouncement of radium as "the modern miracle" and detailing the scientific enticements of his lectures. WHC.

demonstration of it at his lectures, also gave him considerable authority. Advertisements for his lectures (see Fig. 1.4) emphasized his collection of scientific equipment and especially radioactive substances, which "has not been duplicated here or abroad." This collection was not only one of the major draws for his audiences; it demonstrated his expertise in the subjects he lectured on. In advertisements and in his lectures, his own education and training in engineering, and his employment with Edison, were scarcely mentioned.

Hammer's personal connections with leading researchers in radioactivity also contributed to his authority. Throughout the lecture, he was meticulous in giving credit, at times taking pains to list all the major researchers currently at work in a particular area, and always mentioning the names (and in the book, at least, often the complete citation) of the scientists whose work he was presenting. In the section of his lecture on radioactivity, he mentioned personal correspondence with Henri Becquerel, J. J. Thomson, Sir William Crookes, Lord Kelvin, Nikola Tesla, Ernest Rutherford (twice), and, on seven occasions, with Pierre Curie.[58] These names would have been familiar to a layman with an interest in science. What really mattered for his audience to see him as an authority was his personal experiences with radium and its leading researchers: if Pierre Curie considered him deserving of radium, an audience needed no more convincing that he was a trustworthy expert on the subject.

"The Modern Miracle"

When Hammer introduced radium in his lectures, he paused for a moment and requested that the lights be dimmed. The audience sat in darkness for several moments,

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[58] Hammer, *Radium, and Other Radio-Active Substances.*

waiting to see what Hammer would produce. When he felt that their eyes had adapted to the low light, he held up a glowing tube, that cast out a green light.[59] The cotton that swaddled the tube glowed green as well. In the tube was radium, "the modern miracle," as Hammer called it. He held up a few more glowing tubes, containing radium and polonium of different strengths. He walked about the auditorium, holding up these tubes, allowing the audience a closer look.

Although radium was very likely what the majority of the audience was most interested in, or at least had heard most about, Hammer did not confine his remarks to radium, or even to radioactivity. Broadly, he discussed phosphorescent and fluorescent substances before moving on to radioactivity, and then concluding with a discussion of selenium (which, as a photovoltaic material, had interesting applications in electricity) and UV light—the scientific subjects in which he was most interested.[60] Hammer's book contains several phrases like "I hold in my hand," so we can safely take it as the closest thing we have to a script for one of his early lectures. In his lectures, he discussed the discovery of radioactivity and radium—misunderstanding, as we shall see, the implications of the research of Ernest Rutherford and Frederick Soddy—and the variety of effects radium had— on its environment. Considering the wide range of potential

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[59] Radium's glow is actually caused by interactions between radioactivity and impurities in the salt, and not by the element itself. Some samples glowed brighter than others, but there was not necessarily a correlation between brightness and radioactivity. U. S. Department of Commerce, Bureau of Mines. *Radium*, by Paul M. Tyler. Information Circular 6312, August, 1930.

[60] The full title of his book (which is nearly identical to the title of his AIEE / AES lecture) is *Radium, and Other Radio-Active Substances; Polonium, Actinium, and Thorium, With a Consideration of Phosphorescent and Fluorescent Substances, the Properties and Applications of Selenium and the Treatment of Disease by the Ultra-Violet Light*. Photovoltaic materials have a voltage created in them upon exposure to light.

applications popularly speculated upon on the basis of these effects, it is significant that Hammer only discussed the possible medical applications of radium.

After his opening presentation of phosphorescence and fluorescence, Hammer began his section on radium and radioactivity. In Hammer's discussion of radioactivity, he presented the now-familiar story of the discovery of radioactivity and its properties. I want to highlight a few specific points in Hammer's presentation: he did not present Henri Becquerel's discovery of radioactivity as an accident, nor did he lean on the heroic or romantic aspects of the story of the discovery of radium by the Curies, and he completely missed the importance of Ernest Rutherford's work with thorium X. Hammer started his radioactivity section of the lecture with a discussion of Becquerel's 1896 discovery and a demonstration of two sulphates of uranium, loaned to him by a Columbia professor, similar to those used by Becquerel. He told how Becquerel, in experiments with phosphorescence, stored a photographic plate covered with uranium salts in a drawer awaiting a sunny day when he could expose the salts to sunlight and activate their phosphorescence. After some cloudy days "it then occurred to him to develop the plate," Hammer explained, "and much to his surprise he found a well-defined impression upon the plate."[61] Uranium emitted rays of its own accord. In both contemporary and modern discussions of this discovery, it is common to see it presented as an accident, something that Becquerel stumbled upon.[62] Perhaps because of his acquaintance with Becquerel, or

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[61] Hammer, *Radium, and Other Radio-Active Substances*, 12.

[62] For demonstrations in the modern historiography that the presentation of Becquerel's discovery as an accident wrongly discredits his deliberate experimentation, see: Nahum S. Kipnis, "The Window of Opportunity: Logic and Chance in Bequerel's Discovery of Radioactivity," *Physics in Perspective* 2 (2000): 63–99; Lawrence Badash, "Becquerel's 'Unexposed' Photographic Plates," *Isis* 57 (1966): 267–269; Lawrence Badash, "Becquerel's Blunder," *Social Research* 72 (2005): 31–62.

perhaps merely wanting to avoid speculation, Hammer avoided this trope in his lectures. The plates exposed by uranium were a "surprise" to Becquerel, but it was a deliberate decision on his part to investigate them, and this was the way Hammer presented the story to his audience.

Similarly, his audience heard very little romanticization from Hammer in his relating of the discoveries of polonium and radium. It was in investigating the new rays discovered by Becquerel that Marie and Pierre Curie discovered the two new elements. Hammer described how the Curies found that their samples of pitchblende, a uranium-bearing ore, were four times more active than uranium. By a "most painstaking search" via a series of chemical purifications, they succeeded in finding polonium, hundreds of times more active than uranium, and then, with Gustave Bémont, radium, around a million times more active.[63] This was a demanding process, made into a heroic effort in many tellings of the story, but not in Hammer's. The Curies were often put into a romanticized light as well, but Hammer did not play up their early poverty or their love story. What he found interesting, and what he wanted to share with his audience, were the scientific implications of their discovery.

Considering this, and Hammer's scientific proficiency, it is rather surprising that Hammer failed to grasp the idea of radioactive transmutation, put forward by Ernest

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[63] Ibid. Hammer does not name the process, fractional crystallization, used to remove polonium and radium from the ore. He does he describe the piezoelectric electrometer invented by Pierre and his brother Jacques and the key role it played in determining the activity of the Curies' samples. He also mentions that only radium had yet been isolated in quantities enough to demonstrate chemically—rather than by means of radioactivity—that it was a new element. For a detailed description of the experiments and apparatus behind the discovery of radium, see R.F. Mould, "The Discovery of Radium in 1898 by Maria Sklodowska-Curie (1867–1934) and Pierre Curie (1859–1906) with Commentary on Their Life and Times," *British Journal of Radiology* 71 (1998): 1229–1254.

Rutherford and Frederick Soddy a little over a year before the publication of Hammer's book. Hammer capably laid out the distinctions between alpha, beta, and gamma rays, distinctions made in large part by Rutherford. Radium was continually emitting these three rays, though most were alphas. The α rays were easily absorbed and most likely particles, Hammer told his audience; β radiation was moderately penetrating, deflected by a magnetic field, and "in every particular correspond to the characteristics of cathode rays," by then identified as consisting of electrons; and γ rays were very highly penetrating.[64]

However, Hammer missed the significance of Rutherford's work at McGill with Frederick Soddy with thorium and thorium X. Hammer demonstrated a sample of thorium oxide, the substance from which Rutherford and Soddy isolated thorium X, and explained that as "extraordinary as it may seem, it has been found that after separation of the active constituents represented by the ThX from the thorium, that the ThX loses its radioactivity, and this is taken up by the thorium in exactly the amount that the other loses."[65] Hammer seems to have thought that thorium shows an increased activity exactly compensating for the decreased activity of thorium X, whereas what actually happens, as Rutherford and Soddy showed, is that the mass of thorium was continually

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[64] Hammer, *Radium, and Other Radio-Active Substances,* 30. For more on how these rays were categorized and understood, see Wheaton, *The Tiger and the Shark*; Thaddeus J. Trenn, "Rutherford on the Alpha-Beta-Gamma Classification of Radioactive Rays," *Isis* 67 (1976): 61–75; Marjorie Malley, "The Discovery of the Beta Particle," *American Journal of Physics* 39 (December 1971): 1454–1461; Roger Stuewer, "William H. Bragg's Corpuscular Theory of X-Rays and Υ-Rays," *The British Journal for the History of Science* 5 (1971): 258–281. We now understand αs as helium nuclei, βs as electrons, and γs as photons.

[65] Hammer, *Radium, and Other Radio-Active Substances*, 26.

transmuting into thorium X, while the separated sample of thorium X was itself decaying away.

All radioactive substances have their own characteristic half-lives, or rates of decay, and after a certain amount of time radioactive mother and daughter products come into equilibrium. As Rutherford and Soddy observed, eventually the rate at which the daughter product (thorium X) decays away is balanced by the rate at which it is produced by the mother product (thorium) and the amount of thorium and thorium X present reach their maximum, equilibrium values.[66] Rutherford and Soddy realized with this experiment that radioactivity was a subatomic process of disintegration: a radioactive element changing itself into another element or isotope with some characteristic rate of decay.[67] This was a groundbreaking discovery, and while it was only a bit more than a year old when Hammer's book appeared, it is surprising that he completely failed to grasp its significance.

It was after this introduction of the science of radioactivity that Hammer dimmed the lights and held aloft a glowing tube of radium. Even though they had seen glow-in-the-dark paint earlier in the evening, *this* ethereal glow was created by a new element, which was continually giving off energy in a manner not well understood by modern science. Hammer introduced radium with the words,

> Radium is by far the most important [of the radioactive substances] and is of extraordinary interest. It is doubtful whether any substance had been

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[66] For more on the understanding of this discovery, see Marjorie Malley, "The Discovery of Atomic Transmutation: Scientific Styles and Philosophies in France and Britain," *Isis* 70(1979): 213–223.

[67] Ernest Rutherford and Frederick Soddy, "The Radioactivity of Thorium Compounds—II. The Cause and Nature of Radioactivity," *Journal of the Chemical Society, Transactions* 81 (1902): 837–860.

> discovered in the history of the world of such stupendous interest and importance and possessing such puzzling characteristics as radium, which seems so at variance with well-established scientific theories as to the constitution of matter.[68]

The source of radium's energy was not understood, and its ability to give off energy for thousands of years offered a challenge to the accepted theory of the conservation of energy. Hammer carefully explained the puzzle around the source of radium's energy, which was at the time a topic of much discussion among leading scientists.[69] The fact that radium was a marvel not only to the layman but to the scientific expert as well made it all the more impressive.

After his demonstration of radium, Hammer spoke about the effects of its energy, concentrating on effects on glass and gems and its photographic, electric, and physiological effects. Glass was discolored from the effects of radioactivity, and in the presence of radium, diamonds glowed. He recounted the story of how when visiting the Curies in Paris, Pierre Curie held up a bit of radium that caused Hammer's diamond ring to glow. Newspapers would speculate that this power of radium would in future be used to distinguish real gems from paste fakes. The new element's effect on diamond was so well known that once the Tiffany Diamond was allowed to be illuminated by radium.[70]

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[68] Hammer, *Radium, and Other Radio-Active Substances*, 16.

[69] Helge Kragh analyzes how investigations into the cause of radioactive decay were an active field until around 1910, at which point they were tabled as it was realized that theoretical physics lacked the tools necessary to explain subatomic processes. "The Origin of Radioactivity: From Solvable Problem to Unsolved Non-Problem," *Archive for History of Exact Sciences* 50 (1997): 331–358.

[70] This occurred at the famous MIT Sunshine Dinner, discussed later in this chapter. "The Technology Club of New York," *The Technology Review* (Massachusetts Institute of Technology) 6 No. 2 (April, 1904): 247–249.

Hammer presented several radiographs to his audiences as lantern slides, giving them vivid representations of radium's energy (see Figs. 1.5 and 1.6). Radiographs are images created on photographic plates by radioactivity, in this case by radium. Hammer showed his audience radiographs of lenses, a lead box containing radium, a steel tool, various metals, as well as sea shells, a (dead) tarantula, a (dead) scorpion, goldfish he killed by placing radium tubes in their tank, 2 radiographs of (dead) mice, one still in the trap, and a (dismembered) human hand.[71] Many of Hammer's radiographs appear (uncredited) in radium craze newspaper articles preserved in the Hammer collection. These images emphasized the power of radium's energy.

Hammer gave a demonstration of radium discharging an electroscope by ionizing the surrounding air. A gold-leaf electroscope, like the one used by Hammer, is a device used to measure electric charge: two thin gold leaves are suspended from a metal rod in a

[71] "Lecture on Radium by Hammer," Series 1, Box 17, folder 8, WHC.

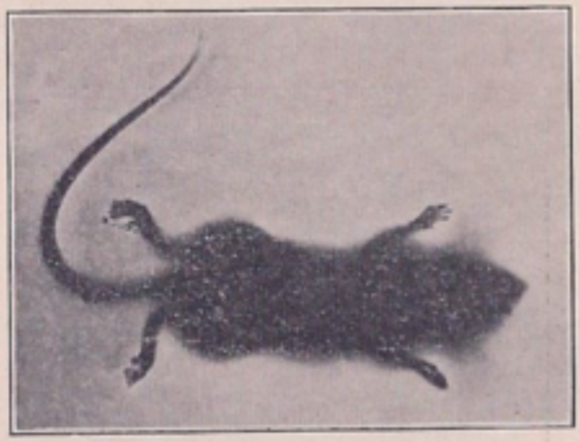

FIG. 10.—Radiograph of a Mouse Made by Radium in Twenty-four Hours

Figure 1.5. Radiograph (photographic exposure with radium) of a a dead mouse, created by Hammer and shown during his lectures. Hammer, Radium, and Other Radio-Active Substances*: 38.*

FIG. 12.—Radiograph of a human hand made by Radium in 8 days' time.

Figure 1.6. Radiograph (photographic exposure with radium) of a a human hand, created by Hammer and shown during his lectures. This would have immediately reminded his audience of the famous X-ray photograph of the hand of Röntgen's wife, that clearly showed her bones and wedding band. Hammer, Radium, and Other Radio-Active Substances*: 38.*

glass jar, and the rod is connected to a metal plate or ball that sits above the jar. In this way, when a charge is applied to the plate or ball, it is conducted through the rod to the gold leaves, which then move apart from each other because they carry the same charge and like charges repel each other. If the electroscope is charged and then brought into the presence of ionized air, the charge on the gold leaves is conducted into the air and they move back towards each other. The radioactivity produced by radium ionizes the air around it, so when a charged electroscope is brought into the vicinity of a sample of radium salts, its leaves fall back towards each other as their charge leaks into the ionized air. There was no way of seeing the invisible alpha, beta, and gamma rays given off by his radium salts, but with his electroscope Hammer could directly demonstrate their presence and, in a sense, allow them to be seen.

After demonstrating with the electroscope how radioactivity permeates the environment around radium, Hammer told the audience, "at the present moment the clothes of every person in this room and all the walls of the room are radioactive."[72] This would not have alarmed his audience the way it would a modern audience—the techno-optimism of the age cast radioactivity in a favorable light, seriously downplaying or even ignoring any potential for harm. Hammer did mention the harmful effects of radioactivity, giving several examples. However, what these burns and injuries were generally used to show—both in Hammer's lecture and in the popular press—was that radium had a definite effect on the body, thus bolstering hopes for its potential therapeutic use.

Hammer mentioned the radium burns suffered by pioneering radioactivity researcher and manufacturer Friedrich Giesel, Henri Becquerel, and the Curies; and he also described how carrying a box containing tubes of radium under his arm burned him as well.[73] He told his audience that Pierre Curie told him "that he would not care to trust himself in a room with a kilo of pure radium, as it would burn all the skin off his body,

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[72] This is a misstatement, unless Hammer had open containers of radium salts. The audience and the hall had been *irradiated* but not made radioactive, unless some radon had escaped into the hall, and subsequently deposited small amounts of ^{218}Po (then known as radium A) onto clothing or the walls in the process of its decay. Hammer, *Radium, and Other Radio-Active Substances*, 24.

[73] In one lecture he stated that Pierre Curie's hands were so badly burned that he could no longer dress himself. "Lecture on Radium by Hammer" [anonymous review of a lecture in Brookline, Massachusetts]; Hammer, *Radium, and Other Radio-Active Substances,* series 1, Box 17, folder 8, WHC.

destroy his eyesight and probably kill him."[74] This statement was widely quoted in the press. This imaginary kilogram of pure radium was definitely frightening, but it also represented four orders of magnitude more radium salts than were available in the world.

Radioactivity researchers had done some animal experimentation, and Hammer described the experiments on guinea pigs and mice on which Pierre Curie had collaborated. Their test animals were paralyzed or killed by exposure to radium. Hammer also discussed his own experimentation with a torpedo (an electric ray) while he was in Italy: immediately after exposing the ray to radium, it was unable to produce any more electric shocks. These results were understood not so much as a demonstration of the dangers of radioactivity, but as physiological support for radium's potential therapeutic efficacy. One report on a lecture of Hammer's picked up on his statement that humans could, like guinea pigs, be paralyzed or killed by radium. To entice readers, newspaper gave the article shocking headlines—"Radium Endangers Life, Warns Expert: Small Piece Would Kill Sleeping Man Probably Within Hour, Lecturer Says: It Paralyzes the Brain"—but within the text, greatly downplayed the risks, characterizing Hammer's statements as "a note of warning on the careless use of the element as a remedy" and quoting his conclusion after this warning that "at the same time, there is much reason to believe that radium in the proper hands will prove a valuable remedial element."[75]

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[74] Hammer, *Radium, and Other Radio-Active Substances,* 27.

[75] "Radium Endangers Life, Warns Expert," *Philadelphia North American* (October 17, 1903). A similar article appeared in the *New York Sun*, presenting Hammer's warnings of paralysis and recounting a story (that I have found no evidence for elsewhere) of Hammer sternly warning a father treating his blind daughter with radium at home, exclaiming, "My God, man! ... Do you know what you are doing? Do you want an imbecile for a child? Do you want her scarred with burns and ulcers, as well as blind? ... It is criminal to experiment with such a powerful substance without your physician's knowledge." "Wonders and Dangers of Radium." *New York Sun* (September 13, 1903).

Optimism about science and technology and faith in scientists and physicians ran high, and shaped popular discussion and understanding of the effects of radium: dead guinea pigs were a sign not of radium's danger, but of its medical potentials.[76]

Hammer largely refrained from speculation on potential applications of radium, but in at least some of his lectures, he explicitly discussed the promises of radium therapy. Radium's physiological effects on lab animals, while injurious or fatal in most early experiments, proved that radium, like X-rays, had an effect on living tissue, and X-rays were already being used therapeutically. Experiments had also been done in the first few years of the twentieth century showing that radium killed microorganisms, leading Hammer and others to speculate publicly about the possible bactericidal effects of certain radium therapies.[77] In a 1903 lecture, Hammer suggested that Kaiser Wilhelm II, who was currently suffering from voice and throat trouble, would be helped by drinking a radium solution, an idea that gained traction in the press as a "radium gargle."[78] These were potentially two areas in which radium had therapeutic advantages over X-rays: X-rays were not understood to be bactericidal, and there was no way to incorporate X-rays into drinks or other internal therapies.

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[76] For a discussion of the social perceptions of science and medicine at this time, when "to the middle-class public, science was a source of moral precepts," (75) see chapter three in Barbara Ehrenreich and Deidre English, *For Her Own Good: 150 Years of Experts' Advice to Women* (New York: Anchor Books, 1978).

[77] The bactericidal effects of radium were investigated by German researchers including Hermann Strebel, who experimented widely with the biological and physiological effects of radium. Even at the time, however, radium's effect on bacteria was not accepted as proven fact, and it was ultimately not borne out by further research.

[78] Letter of November 14, 1903, series 1, Box 17, folder 6, WHC.

Hammer told his early audiences about the favorable treatments already achieved with radium in Europe in cases of cancer and lupus, and theorized about its applications in blindness and how some hot springs may be healthful because of their radioactivity—an idea very popular in Europe, and which would later catch on to some extent in the States.[79] The "Berlin school" of radium therapy, as characterized by Claudia Clark in *Radium Girls*, was founded on beliefs that spas were beneficial because of the radioactivity of their waters, and that the miners of St. Joachimsthal (the source of the Curies' pitchblende) were healthy because of the radiation they breathed.[80]

Hammer gave a serious presentation of the science of radioactivity in his lectures, explaining its discovery and effects to the best of his understanding. There are few records of the reception of his lectures, but they seemed to draw large audiences. One audience kept him on stage after his lecture until midnight, asking questions and requesting closer demonstrations, which is very suggestive of the interest his presentations sparked.[81] He refrained from wild imaginings about radium's future uses, and confined his speculation about its applications to medicine, where it was already beginning to show promise. Hammer stressed the novelty of radium, its properties, and

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[79] "Lecture on Radium by Hammer," Series 1, Box 17, folder 8, WHC. The issue Hammer (purportedly) took with the father treating his daughter's blindness (see note 36) was not the use of radium in treating blindness but rather its medical application by a non-professional.

[80] Clark describes the American style of radium therapy as incorporating elements of this Berlin school. She argues that the American style of radium therapy also shared some similarities with the "French school," which was centered around Paris's Laboratoire Biologique du Radium and its journal, *Le Radium*. The radium waters and emanatoria, where radium emanation could be breathed in, both enjoyed popularity in the United States, and *Radium,* the house journal of the Standard Chemical Company, was influential in American radium therapy, as we shall see in a later chapter. Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910–1935* (Chapel Hill: The University of North Carolina Press, 1997).

[81] Letter of October 28, 1903 from William Hammer to James Beck, Series 1, Box 3, folder 10, WHC.

its energy—all of this illustrated by one of his tubes of radium, held aloft in a darkened room and throwing off a faint glow.

Radium in the Press

To keep abreast of the press coverage on radium and other topics that interested him, Hammer employed a clipping service that sent him articles from newspapers across the country. At the height of the radium craze, Hammer collected these articles and pasted them into scrapbooks, sometimes making notes to himself in the margins. The scrapbooks from 1903 and1904 have been preserved in the Hammer Collection at the Smithsonian, and they fill nearly five archival boxes. Although the service was clipping articles on a range of topics, including a variety of radiations and advances in electricity, the overwhelming majority of the articles focus on radium, demonstrating the enormous interest in radium during this period. These articles provide a valuable resource in understanding the radium craze and how radium was perceived by the public.[82]

Radium was fascinating because of its properties and possible applications, and popular speculation ran rampant in these areas.[83] The most common themes in radium craze articles are radium's cost, its energy, and its medical potential. In this subsection, I will discuss these three themes in turn.

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[82] For some of the analysis in this section, I have drawn from additional, digitized, sources of newspapers from this period, but most articles are found in the Hammer Collection.

[83] Lavine finds press coverage of therapeutic possibilities of radium to be characteristic only of later periods in his dissertation, but I have found medical speculation to be a significant portion of press reports on radium. Lavine, "A Cultural History of Radiation and Radioactivity in the United States," 139–140. In *Nuclear Fear*, Spencer Weart argues that much of the popular imagery around radioactivity had been carried over from previous associations with electricity (and that these images were rooted in ancient symbols of life rays and death rays). Weart, *Nuclear Fear: A History of Images* (Cambridge: Harvard University Press, 1988):41–47.

Figure 1.7. Attendees of the MIT Sunshine Dinner. "Sunshine Dinner Held at the University Club," New York Herald *(February 6, 1904).*

All of these themes were reflected in a New York City society event that attracted great press attention (see Fig. 1.7). Wanting to honor the new element and borrow its considerable popular cachet, the MIT Technology Club of New York themed their annual dinner in 1904 around radium. At this exclusive dinner, the hundred and thirty guests were entertained by fluorescent decorations, a radium-powered perpetual motion machine (a reference to the limitless, or effectively limitless, supply of energy that radium was continually emitting), and glowing skeletons that danced in the dark (see Fig. 1.8). In the darkened ballroom, radium cocktails were served and the diners raised their glimmering glasses in a toast. Being one of the few actual (and not exclusively medical) uses of radium, and involving New York high society, the event garnered huge attention in the press. The dinner was held less than a month after the MIT Technology Club heard a lecture by William Morton, the physician who created a combination radium/X-ray internal therapy called "liquid sunshine," and the dinner was named the "MIT Liquid Sunshine Dinner" in the press. The evening's entertainments emphasized the marvels of radium's energy—and the Club's interest in theming their dinner around radium demonstrates both the scientific excitement around it and the social prestige it enjoyed thanks to its great expense. The radium cocktails encapsulated both of these themes, as well as radium's medical importance, as the diners (and the press) understood them as, at

Figure 1.8. Newspaper illustration of imagery from the Sunshine Dinner. The skeletons demonstrate the connections with X-rays; radium's glow and its energy are illustrated by the radiating lines, and its importance for science is represented by the laboratory glassware and the demonstrator's hand holding a rod (possibly a conductive metal rod used to discharge an electroscope, to explain the ability of air ionized by radium to also discharge an electroscope). "Sunshine Dinner Held at the University Club," New York Herald *(February 6, 1904).*

least symbolically, healthful, rejuvenating tonics.

Cleveland Moffett, one of the journalists invited to the dinner, was unimpressed, finding the "radium" paint to be ordinary fluorescent paint and the perpetual motion machine out of order. His skepticism was atypical of the flood of overwhelmingly positive reports on the dinner. These reports generally highlighted the liquid sunshine drinks, powerful symbols of radium's energy and purported health benefits. The radium cocktails did apparently contain tiny tubes of radium salts—though they must have been very weak, impure preparations for the club to obtain enough tubes for all of the guests. In their report to the MIT alumni publication, the club explained that the cocktails contained aesculin, an extract from horse chestnuts that fluoresces blue, in addition to the radium capsules.[84] To encourage the fluorescence, magnesium wire was burned.[85] These aids were not mentioned in accounts of the dinner in newspapers; in these it was radium alone that made the cocktails glow. Moffett, however, was disappointed in the drinks as well, writing that they "gave out less light when the room was darkened than half a dozen healthy fireflies would give a New Jersey field."[86] Many accounts played up the extravagance and wealth of such a banquet: it was truly the height of fashion in 1904 to serve glowing radium cocktails, a luxury only within the reach of well-to-do savants.

Cleveland Moffett's skepticism is an example of the small amount of negative reactions provoked by the radium craze. As might be expected for such a large cultural

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[84] Morton also administered aesculin in some of his therapies. William James Morton, "Fluorescence Artificially Produced in the Human Organism: By the X-Ray, By Radium, and By Electric Discharge, As a Therapeutic Method," *JAMA* 44 (1905): 1013.

[85] "The Technology Club of New York," *The Technology Review* 6 (1904): 247–249. Magnesium burns with an extremely bright white light, and has a powerful effect on fluorescent substances.

[86] Cleveland Moffett, "The Sense and Nonsense about Radium," *Success* VII No. 119 (April, 1904): 245–248.

phenomenon, there was some backlash. In his article on the Sunshine Dinner, Moffett admitted that there was some promise for radium in treating skin diseases but he bemoaned the fact that radium has gotten up the hopes of cancer and consumption patients, most of whom could get no benefit from it. "I fear people will continue to suffer and die in spite of radium," he wrote, "and doubt if the laws of existence or matter will be very seriously disturbed because we have some pinches of white powder that behaves queerly."[87] Another article preemptively declared that "The Radium Craze is Over" in April of 1904, while others decried the sensationalism surrounding radium and the "humbugs" such sensationalism encouraged.[88]

These negative reports were a vehement but small minority of the articles on radium. One *Washington Post* article summarized the major claims being made for radium and poured cold water on them all, declaring "Stories of [Radium's] Marvelous Powers Mainly Bosh: Superlative Cost a Fantasy: Won't Restore Sight to the Blind, Won't Cure Cancer, Is Not as Strong as the X-rays, and Germs Are Merely Stimulated."[89] A handful of negative reports didn't change the general popular beliefs that that radium might be of great medical aid and rivaled the power of X-rays. The overall impression conveyed to the public by the press was that radium *did* have "marvelous powers," that the future might be lit by eternal radium lamps, and that the most dread diseases facing modern society might be conquered by the rays of radium.

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[87] Ibid., 247.

[88] "The Radium Craze is Over," *Detroit News,* April 16, 1904. "Radiant Humbugs," *Buffalo Times*, January 31, 1904.

[89] "Bogus Radium Claims," *Washington Post*, May 8, 1904.

Radium was, by weight, the most expensive substance on the world market. The price of radium was the focus of many articles, with titles like "Radium May Be Found Anywhere: You Should, Therefore, Be On Lookout For It," and "Chorus Girl Has Radium Deposit (?)."[90] The *Macon News* summarized how radium's costliness lent it cachet, writing, "No one knows what to do with it, but everybody wants a bit because it costs much more than a diamond of the same size."[91] In 1903, the *New York Evening Journal* introduced its readers to a new radiumized casino in New York City, inspired by one in Paris. In darkened rooms, the patrons sipped expensive cocktails and played roulette in eerie silence. Diamonds shone faintly in the light of the radium-painted roulette wheel. Bets were placed with green-glowing chips, and the roulette ball sparked as it jumped around the wheel.[92] The casino was very likely a complete fabrication, but

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[90] "Radium May Be Found Anywhere," *Baltimore American*, December 16, 1903. "Chorus Girl Has Radium (?)," *Buffalo News*, August 2, 1903. The December 17, 1903 issue of the *Richmond News Leader* ran a short piece running: "Mr. William J. Hammer, consulting electrical engineer, of New York city [sic], says radium can be found everywhere, but a search of our pockets fails to verify the statement." There were also reports of the theft of a tube of radium belonging to Chicago physician William Pusey, for example, "Burglar Stole Tube of Radium," *New York American*, May 8, 1904. It is unclear if this was actually a theft or simply a loss of radium that the newspapers inflated into burglary. However, Philadelphia radium therapist William Clark did, at some point, have around 50 mg. of radium stolen. Philadelphia radium hunter Frank Hartman was brought in, as were policemen, detectives, and lawyers, but, according to Hartman, "this radium was never returned, due to some personal grudge against Dr. Clark by one of his former employees." The College of Physicians of Philadelphia, Historical Medical Library, Frank J. Hartman papers, 1904–1907: Box 2, Series 2, Folder 5, Hartman Radium Diary.

[91] (Untitled article), *Macon [Georgia] News*, December 21, 1903. There was another article that placed radium in a definitely un-glamorous location: The *Commercial Advertiser* ran an article in 1903 on "Radium Hen Food," presenting the opinion of "Mr. Hobbs of Washington Market" that, what with the price of eggs, it would soon be cost-efficient to feed hens radium, which would encourage laying and have the side benefits of self-incubating and -boiling eggs (depending on whether the eggs were fertilized or not, one would hope). "The chick might send out sparks in the dark like a sputtering fire-cracker," Hobbs admitted, "but when all the chicks started to do it I reckon the hens would take it all for granted." "Radium Hen Food," (New York) *Commercial Advertiser*, December 16, 1903.

[92] "Radium Roulette a New York Rage," *New York Evening Journal*, July 30, 1904.

this imagined space illustrates the social prestige radium enjoyed because of its cost: an almost unprecedented level of popularity and fashionability for a scientific discovery.

As radium was so expensive, there was also popular discussion of the supply of radium. Many newspapers ran reports of possible local discoveries of radium; these were so common that the local paper for Muncie, Indiana ran an article in 1903 announcing that radium had *not* yet been found in the state.[93] *The Western Miner and Financier* considered radium to be of enough commercial interest that it dedicated one of its 1904 issues entirely to the element.[94] There were also articles about a shadowy European "radium trust" greedily hoarding radium and keeping it out of the hands of deserving researchers. France and Germany were the only suppliers of radium in the world, and 1903 reports on this state of affairs were apparently distorted into rumors of a sinister radium trust. Many scientists and physicians were frustrated that the supply of radium was so limited; and this frustration was evident to the press, who found it convenient or compelling to blame an imaginary cabal of industrialists intentionally limiting the supply of radium.

The great cost of radium also made it a popular subject for cartoons, and many of these cartoons were sent to Hammer by his clipping service. The *New York Journal* ran a single-panel cartoon where a girl turns down her messenger boy suitor saying, "Until yer can build me a house outen radium, Algernon, it can't never be."[95] The *New York*

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93 "Radium Has Not Been Found: Just Why it Does Not Exist in Indiana, is Unknown," *Muncie Times*, December 11, 1903.

94 *The Western Miner and Financier* 10 No. 11 (March 17, 1904).

95 "Expensive Love," *New York Journal*, May 26, 1904.

Evening World ran a page of comics titled “When Radium Puts Money Out of Business,” depicting burglars ignoring “money and joolry” for radium; a man snubbing his nose at the high price of coal, declaring “I heat the flat with radium!!”; Rockefeller writing a check for a pound of radium and flooding his competitors’ radium mines; fat cats with radium pens, rings, buttons, and watch fobs, glowing brightly; and society matrons wearing so much radium as jewelry that no lights are needed to illuminate the aisles at a show. In another comic page, a woman, sitting on a chair printed with dollar signs, warmed herself at a brightly shining radium heater (see Fig. 1.9).[96] These images, and similar ones, focus on radium’s cost; its other properties are incidental at best. There is no implication that the high society ladies and gentlemen would receive burns from their jewelry, for example. Although radium’s ability to burn was generally presented in a positive light in the American press, as evidence of its medical potential, it was common knowledge that radium burned the skin. This emphasizes the humorous nature of these imaginings—newspaper readers would have been well aware that a radium watch fob

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[96] “When Radium Puts Money Out of Business,” *New York Evening World*, September 9, 1903. A similar page was run by the *New Jersey Evening News*: a pretty young girl, presented with a speck of glowing uranium by an ugly old man, declares. “I’ll marry you today”; a man offers two million dollars to a firefighter to save his polonium from his burning home. William Hammer also made his way into this cartoon, trying to pawn a tiny bit of radium for a million dollars (though the man identified as “millionaire Bill Hammer” looks nothing like real-world non-millionaire William Hammer). “Some Reflections on the Future of the Priceless New Metals, Uranium, Radium and Polonium,” *Evening News* (New Jersey), June 16, 1903.

Figure 1.9. This panel illustrates radium's great expense and seemingly inexhaustible energy—while ignoring its physiological effects so as not to detract from the joke. "When Radium Puts Money Out of Business," New York Evening World*, September 9, 1903.*

would burn the wearer. These cartoons also underscore the familiarity of the American public with the idea of radium—the cartoonists could safely assume their readers understood the basics of the physics of the new element.

Another major focus of reports on radium was its energy. Articles that focused on the energy of radium were, characteristic of reporting in this era, hyperbolic in their descriptions of it. At this time many newspapers were competing for the attentions of the large segment of the public interested in scandal, romance, and drama—those people who, as William Randolph Hearst had it, were drawn to "the interesting" rather than "the important."[97] In the articles on the impact of radium's energy on science, radium

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[97] Quoted in Helen MacGill Hughes, "The Social Interpretation of News," *Annals of the American Academy of Political and Social Science* 219 (1942): 11–17. This and other articles by Hughes are excellent sources for understanding journalism and human interest stories at the turn of the century.

smashed the accepted ideas of physics and chemistry, overthrew the conservation of energy, and promised to unlock the secrets of the sun, sex, and life on earth.[98]

There was a flurry of excitement in 1905 around an announcement that John Butler Burke, of Cambridge, had possibly created life in sterilized bouillon by the introduction of radium. Burke characterized his "radiobes" as displaying some characteristics of crystal growth, and some of bacterial growth, but that they were unlike any life ever seen before.[99] There was speculation that radioactive energy, or the energy from radium specifically, could have been the spark that first created life. American reporters went to Hammer for his opinion on the discovery, and he was open to the possibility that radium could create life. He held this belief because Burke had worked with well-respected physicist J. J. Thomson, but mostly because "I am inclined to believe almost anything that is claimed by respectable authorities for radium, as my own investigations have convinced me that we are only beginning to dimly realize its wonderful qualities."[100] This is very telling of the general tone of the radium craze: a trusted public intellectual expected marvels from the energy of the new element—and the American press and public did as well.

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[98] The speculation on the sun's energy was based on a suggestion made by William Wilson and George Darwin (son of Charles). A Russian scientist claimed in 1904 to have used radium to determine the sex of unborn children; American newspapers reported on this, unsurprisingly, with ambiguous, titillating headlines like "Secret of Sex Found in Radium," *New York Evening Journal*, January 28, 1904. Charles Baskerville's 1904 report that he had isolated two new elements, carolinium and berzelium, occurred at the height of the radium craze and so received a good deal of coverage in the press (though the elements were found to not exist).

[99] Burke's experiments were never successfully repeated, and thus were ultimately forgotten. Luis Campos analyzes the vitalistic imagery often used in description of radium in "The Birth of Living Radium," *Representations* 97 (2007): 1–27.

[100] "Radium May Truly Prove the Germ of Life," *New York Evening World* June 20, 1905.

As was well known to the American public, radium salts maintained a temperature higher than their environment and ejected particles and rays without outside influence.[101] A number of analogies emerged to illustrate the unprecedented amounts of energy contained within radium. At the height of the radium craze it was practically common knowledge that a pinch of radium could propel a ship across the Atlantic, or that one ounce of it could lift the entire British fleet a mile into the air.[102] These images conflated the accessible energy radium released as radioactivity and the as-yet inaccessible internal energy that was surmised to be the generator of this radioactivity—but they were symbolic of the vast stores of energy being slowly released by radioactive elements.

The *World* ran a two-page comic featuring their character Mr. Butt-In encountering radium that illustrates the popular associations with radium's energy (see Fig. 1.10). Mr. Butt-In visited Prof. Bangupski's laboratory, where radium was part of an "Exhibition of High Explosives," in a room decorated with signs reading "The Radio Activity of Radium Is 392,456,751 Miles Per Second," "Radium Will Cure Ham,—Or Anything Else," "Blindness Cured By Radium (If You Can See Enough Of It)," "One Grain of Radium Will Sink the U.S. Navy (Mebby)" and "Radium Will Move the Earth."

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[101] Journalists found literary precedents for radium's energy in *Gulliver's Travels* and *The Coming Race*. Readers often saw radium compared to Swift's Laputans trying to extract sunshine from cucumbers and in Bulwer-Lytton's *vril*, a weird source of energy for the subterranean Vril-ya. Edward Bulwer-Lytton, *Vril: The Power of the Coming Race* (first published in 1871). Bulwer-Lytton's novel is not as well known today as Swift's, but around the turn of the century it was popularly known and "vril" was still commonly used synonymously with "energy;" for example, Bovril, a beef extract still produced in Britain, was named by combining the Latin word for ox, *bos*, with vril. W.P. Thompson, *Handbook of Patent Law of All Countries* (London: Stevens & Sons, 1920): 42. Available online at archive.org/details/handbookofpatent00thomiala.

[102] The latter is due to Sir William Crookes.

He mistook radium for snuff and his resulting 2 million dollar sneeze propelled him out the window and into the harbor, where he destroyed a cable car, sank two ships, and collapsed a bridge. Luckily, he "sneezed the radium out of his system," so his health was not in danger.[103]

Figure 1.10. Panels 6 and 8 from the eight-panel "Radio Activity of Mr. Butt-In—Radium's Latest Marvel," The World*, February 21, 1904.*

A fictional newspaper piece, "Cooney Jessap's Overdose of Radium" by novelist George Randolph Chester, also incorporates many of the popular themes around radium's energy. Cunningham "Cooney" Jessap had a penchant for swallowing strange things, so when a traveling lecturer visited his country town to speak on radium, he promptly swallowed his tube of the substance. Jessap began to glow, even during the day, and his internal organs became plainly visible. A secret kiss with a local sweetheart caused her lips to swell and blister; afterwards he dreamed he went to the big city where he met and married a freak-show entertainer who could not be burned by anything, and together they

[103] "Radio Activity of Mr. Butt-In—Radium's Latest Marvel," *The World*, February 21, 1904.

had a daughter named Phoenix and a son named Asbestos.[104] This story plays on many of the popular associations with radium's energy: the glow it gives off continually, its symbolic connection with X-rays in the eyes of the American press, and most of all, the fact that it burns the skin—all very familiar properties at the height of the radium craze.[105]

Radium's energy was also cast in a sinister light at times. Some papers went even further, for example in one article the *Omaha News* grimly announced that "One Pound Could Destroy Earth," though the news was not as alarming as it sounded since there was nowhere near a pound yet in existence.[106] Stories like these are among the first rumblings that something like an atomic bomb might be possible; that term itself was coined by H. G. Wells in his 1914 novel, *The World Set Free*, which he dedicated to Frederick Soddy's *The Interpretation of Radium* as acknowledgement for the influence it had on his

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[104] George Randolph Chester, "Cooney Jessap's Overdose of Radium," *Indianapolis Journal*, February 21, 1904.

[105] Readers were drawn to the very common themes that radium touched upon. Spencer Weart analyzes these themes in *Nuclear Fear*, arguing that radium and radioactivity were compelling because they embodied certain basic, enduring tropes, such as the transmutation of matter (the great dream of alchemists), the power to cause harm from a distance (an accusation against witches), and the connections between heat, light, and life-force. Weart, *Nuclear Fear*.

[106] "One Pound Could Destroy Earth," *Omaha News,* September 27, 1903.

thinking.[107] The potential of weaponizing radium did not dim the popular interest in it, however; rather, it served to further underscore its vast internal stores of energy.

A third large category of the radium craze reporting was the new element's medical potentials. Press speculation about radium's effects on the human body (both diseased and healthy) was rampant. In Georgia, the *Macon News* ran an absurd article willfully misunderstanding an announcement that radium emanation (now called radon) had been discovered in New Haven.[108] The article imagined that radium permeated every aspect of life there: lobsters are radioactive, and residents take radium in their tea (see Fig. 1.11). A doctor there diagnosed a chest pain as a "slight molecular discharge" caused by ingesting radium, and prescribes his blue antidote to be taken with dinner, eaten by X-ray light so that the radioactive foods might be avoided. "Be careful of all sea food," he cautioned his patient, "which is usually uncommonly full of uncooked liquid sunshine

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[107] Soddy was one of the central figures in the international popularization of radium. *The Interpretation of Radium*, written in 1908, is largely scientific, but he allows himself to speculate about atomic energy in the last chapter. Soddy sees humanity, standing before the possibility of atomic energy, in a similar position to when we stood before the invention of fire. He considered atomic energy almost a way of conquering entropy: 'we are no longer merely the dying inhabitants of a world itself slowly dying, for the world, as we have seen, has in itself, in the internal energy of its own material constituents, the means, if not the ability, to rejuvenate itself perennially.' He even included a picture of the Ouroboros, a snake devouring its own tail, to remind the reader of the symbolism he is drawing from. The moral of his last chapter is that 'there is no limit to the amount of energy in the world available to support life, save only the limit imposed by the boundaries of knowledge.' This was a theme of most of Soddy's popular work on atomic energy. His ideas about the possibilities of radium were scarcely less fantastic than those that appeared in the newspapers. Frederick Soddy, *The Interpretation of Radium: Being the Substance of Six Free Popular Experimental Lectures Delivered at the University of Glasgow, 1908* (New York: G. P. Putnam's Sons, 1909). (Accessed April 2009 at http://fax.libs.uga.edu/QD181xR1xS679/1f/interpretation_of_radium.pdf), 239, 249. See Weart, *Nuclear Fear*: 3–16 for a detailed discussion of the symbolism in Soddy's work and the alchemical imagery around the idea of transmutation.

[108] The original reports were a series of articles appearing in the *American Journal of Science*; for example, H. A. Bumstead and L. P. Wheeler, "On the Properties of a Radio-Active Gas found in the Soil and Water near New Haven," *American Journal of Science* 167 (1904): 97–111.

[radium] and should never be served without an X-ray machine."[109] This humorous article mixes both harmful and beneficial effects of radioactivity; if anything, it suggests that New Haven residents ought to take radioactivity, like any other health supplement, in moderation. What is clearly demonstrated by this article is the familiarity its readers had with the idea that radium had definite effects on the body.

Figure 1.11. A New Haven diner taking radium with his tea. "Radium in Lobsters the Latest," (New York) Globe and Commercial Advertiser *(February 1, 1904).*

Cartoonist Albert Levering also joked about the physiological effects of radium. In a full page of panels titled "The Wonders of Radium Practically Applied" (see Fig. 1.12), he drew radium lending speed, intelligence, wit, and health to its users. The glowing substance is a cure-all for a variety of physical and societal ills, including

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[109] "Radium in Lobsters the Latest," (New York) *Globe and Commercial Advertiser* (February 1, 1904).

hangovers, bothersome collectors, and boring dinner parties.[110] Radium appears as a magic wand in nearly all these panels, a clear visual shorthand for its mysterious properties and effects and its unlimited potential in the public imagination.

Figure 1.12. These images of radium clearly present it as a kind of magic wand, capable of any number of marvels. Albert Levering, "The Wonders of Radium Practically Illustrated," clipping ca. 1904 from an unknown magazine, WHC.

Much of the inspiration for works like Levering's cartoon and "Radium in Lobsters" came from actual reports of experiments with radium in medicine. X-rays had already made a splash with their diagnostic and therapeutic potential, and it seemed now that physics had produced another medical marvel. The American press was, unsurprisingly, especially enthusiastic about radium's potential in diseases that were difficult or impossible to cure—there was great drama, and sales, in stories of patients cured of longstanding cancers or made to see after years of blindness.

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[110] Albert Levering, "The Wonders of Radium Practically Illustrated," clipping ca. 1904 from an unknown magazine, WHC.

One might expect American reports on achieved treatments to be mainly about European radium therapists, as most of the radium, and therefore work with it, was concentrated there, but many are on domestic physicians who had obtained small samples. Considering the small supply of radium and the fact that physicians had to connect with radioactive networks to obtain radium, we can safely assume that the majority of these American physicians possessing radium at the height of the radium craze had very small and very impure sample.

Figure 1.13. An illustration of radium salts used in the treatment of diphtheria. Lines radiating from a central source were a common visual code for the radioactivity emitted by radium; in this example they are bathing germs in their energy. Clipping ca. 1904 from an unknown Hearst newspaper, WHC.

Cures of a variety of ailments, from acne to wifebeating, were attributed to radium in the press (see Fig. 1.13).[111] Tuberculosis and especially cancer were the diseases that most distressed the public mind at the turn of the century, and they were

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[111] The wifebeater apparently was only abusive when he sleepwalked, a condition that was cured by application of radium. "Tamed a Wifebeater," *Springfield Union* (Massachusetts), February 21, 1904. Early in 1904 there was even a report, complete with photo, of a wealthy family's pet dog made well by radium. "'Lady Peggy' Cured by Radium," *New York Evening Telegram*, February 19, 1904.

mentioned most often in connection with radium therapy. There was much serious work being done with radium in the treatment of skin cancers, so there were many opportunities for the press to write sensational headlines claiming cancer cures.[112]

There were also a great many local interest stories on radium therapy. In Hammer's newspaper clippings, there are reports of local doctors acquiring radium in Lowell, Masachusetts, Sandusky, Ohio ("after seven months of almost continuous correspondence" with the German manufacturer), and in Atlanta, Georgia.[113] The Atlanta paper claimed Dr. Wolff was the only physician with radium in the South, with a newly-acquired $50 sample intended for experimentation only. Local newspapers also deemed radium therapy treatments interesting: the Davenport, Iowa (a town on the border with

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[112] Also large on the press's radar, but on the far fringe of medical science, were experiments with radiation and skin color. In the press clippings in the Hammer Collection, there are several articles on bleaching black skin with radium and X-rays, and Carolyn Thomas de la Peña analyzes these and others in her article "'Bleaching the Ethiopian.'" She argues that stories of technologically whitened African Americans were compelling to white Americans because it reassured them that "natural" racial boundaries could not be breached, even by a marvel like radium. Sensationalist reports imagined mothers lining up, begging scientists to lighten their children's skin—reinforcing the privileged status of white skin. And even if the experiments concluded successfully (and one Flower Hospital physician was quoted as saying that bleaching all of a person's skin with radiation would result in fatal burns), commenters in the press quickly established that this technologically-achieved whitening would not change fundamental racial qualities. It seems likely that fewer than ten people were actually irradiated in such experiments, and no definite cases of lightening—even of a small patch of skin—were reported with them, so hopefully no one was seriously burned. Articles on these experiments, though largely fabricated, added to the literally biblical implications of radium. Radium could apparently achieve what the Bible thought impossible: "Can the Ethiopian change his skin, or the leopard his spots?" (Jeremiah 13.23). Two articles in the Hammer Collection even invent experiments, complete with photographs, where a leopard has his spots removed with radium. Carolyn Thomas de la Peña, "'Bleaching the Ethiopian': Desegregating Race and Technology through Early X-Ray Experiments," *Technology and Culture* 47 (2006): 27–55. "X Ray to Turn Black Men White," *New York American*, December 28, 1903. "X-Rays Don't Turn Negro White, Says Professor Pancoast," *Philadelphia North American*, January 10, 1904. "Burning Out Birthmarks, Blemishes of the Skin and Even Turning a Negro White with the Magic Rays of Radium, the New Mystery of Science!" *New York American*, January 10, 1904.

[113] "Radium," *Courier* [Lowell, Massachusetts] (January 23, 1904). "Dr. Chas. H. Merz Receives Radium from Germany," *Sandusky [Ohio] Journal* (February 3, 1904). "Atlanta Doctor is First to Use Radium," *Journal* [Atlanta] (March 16, 1904).

Illinois) paper reported on the development of a new radium therapy applicator by a Chicago physician.[114] Reports of individual treatments like that of a Philadelphia optometrist treating a blinded tailor with radium were fairly common.[115]

The *New York Times* printed a poem entitled "Modern Medicine" by J. W. Foley in 1904 that placed radium, along with X-rays, electricity, and "medicineless medicine," at the vanguard of modern medicine, of which the author took a dim view. Dr. Uptosnuf diagnosed his patient Jim with cancer and

> Thus having diagnosed the case with marvelous lucidity
> He said: "I'm sure that radium will heal it with rapidity.
> Where other healers might employ some treatment wholly blunderful
> We shall achieve with radium a cure complete and wonderful."
> But when Jim's fingers for some days were tempered in the crucible
> of radium the doctor found the swelling irreducible
> ...
> "Do you," he asked, "of pain denote a slight degree of lessiveness?"
> But Jim declared he only felt a most distinct progressiveness.
> The heat, he said, was pepperous,
> The ailment was obstreperous.[116]

Jim was finally cured when he went to Dr. Sensible, who declared that he had warts, not cancer. Of all the modern therapies that Foley lampoons, radium receives the most attention, but it is the quack doctor who receives his scorn, not the radium itself (which does have an effect, though not a positive one, on poor Jim).[117] This satirical view of

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114 "Think Radium Will Cure Deep-Seated Cancer," *Davenport [Iowa] Democrat* (January 17, 1904).

115 "Sight Returned by Use of Radium," *Signal* [Zanesville, Ohio] (January 25, 1904).

116 J. W. Foley, "Modern Medicine," *New York Times* May 2, 1904: 8.

117 Even Dr. Sensible is criticized, as he "took a fee right needily / I might say almost greedily." Ibid.

radium therapy was uncommon during the radium craze, but the poem demonstrates radium's enormous popularity at the time.

Throughout this early period, radium's energy and its effects amazed the American public. Its ability to shine out in the darkness, completely of its own accord, was the dramatic high point of William Hammer's public lectures and was so fundamental to its popular identity that it was often referred to as liquid sunshine. Its great internal stores of energy added to its mystery and led to rampant speculation on its future applications in fields ranging from farming to fuel for transatlantic liners. As we have seen, popular discussions of radium were overwhelmingly optimistic. A significant amount of the press coverage on radium focused on its potential and actual use in medicine. Hammer introduced "the modern miracle" to the United States public, and, with their patients in the grips of the national radium craze, physicians began to look for possibly miraculous results within the newly-forming field of radium therapy.

Chapter Two

Early Adopters: American Radium Therapy, 1900–1910

Introduction

In the first decade of the twentieth century, radium therapy was a brand new, experimental therapy being used by a handful of physicians. Connections with physicists and radioactivity research networks were crucial for many physicians to acquire radium, and in some cases these connections spurred physicians' initial interest in radium therapy. More detailed knowledge of the physics of radium also had an impact on the development of radium therapy in this period—specifically, the identification of the three kinds of rays emanating from radium salts and techniques by which radium therapy might selectively employ one kind. The character of radium therapy in the first decade of the twentieth century was empirical, but physics helped to delineate the boundaries within which clinical experimentation occurred.

The first decade of the twentieth century is a distinct period in American radium therapy largely because of the influence of the radium craze, which dominated public discussion of the new element through most of this decade. Beginning in 1911, American radium therapy changed. The most significant of these changes included the establishment of the American radium industry, which increased the supply of medical radium and changed the character of radium therapy, and the transformation of radium therapy into a hospital-based therapy. In the early experimental period of 1900 to 1910, however, radium therapy was based in the private practices of interested physicians.

This chapter opens with a discussion of the experimental and empirical character of early radium therapy, investigating the influences of the radium craze and tracing the variety of forms of radium therapy. The radium craze fostered interest in radium therapy on the part of both patients and some physicians, but the runaway optimism and exaggeration of the media also led the medical profession in general to be deeply skeptical of the new physical therapy. Medical uses of radium ran along two main lines, internal and external, both motivated largely by empirical clinical successes rather than solid theoretical foundations. Experimentation with radium led to an important new method of application—afterloading—and an increased awareness of the dangers of the burns produced by overexposure.

The focus of the next section is the radioactive networks radium therapists engaged with to learn about radium, acquire it, and apply it in their practices. Connections with these networks were crucial for borrowing or purchasing radium for therapy. Additionally, the prestige of science and scientists reflected well on the young field of radium therapy in the eyes of the public—and at rare times physicists were themselves present in the radium therapy clinic. The section concludes with an analysis of the importance of ties with radioactive networks in the case of four influential early adopters of radium therapy.

The final section of this chapter examines the contemporary understanding of the physics of radioactivity and the impact of this understanding on radium therapy. Physicists distinguished three kinds of rays emanating from radium salts, and traced the succession of radioactive daughter products present in these salts. The different radioactive elements in radium salts produced different rays, and many radium therapists preferred the use of certain rays in their therapy. The physics of radioactivity therefore gained an important role in the clinic, evident in an analysis of the articles on radium therapy appearing in the *Journal of the American Medical Association* in the first decade of the century.

Early Radium Therapy

Radium therapy was empirical in nature in this period. Radium therapy developed along two main lines, internal and external therapy. In both areas dosage was highly dependent upon the individual physician and his or her experiences. Radium was used to treat a variety of ailments, but had much early success in the treatment of superficial cancers. This was much publicized in the press, as cancer was becoming one of America's greatest public health fears.[118] This first decade was the experimental period of radium therapy, characterized by interested individual physicians testing the capabilities and limits of the new element.

Radium was a household name and its popularity had a definite impact on radium therapy. Early radium therapists sometimes echoed the language of the newspapers, as well as their enthusiasm for the new element. In a 1903 medical journal, for example, radium therapist Margaret Cleaves spoke of radium as "magical," "fairy lore," and

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[118] For more on this, see, for example, Robert Aronowitz, *Unnatural History: Breast Cancer and American Society* (New York: Cambridge University Press, 2007) and Barron Lerner, *The Breast Cancer Wars: Hope, Fear, and the Pursuit of a Cure in Twentieth-Century America* (New York: Oxford University Press, 2001).

possibly "a veritable Aladdin's lamp to medical science as well as physics."[119] Some early adopters found this popularity to be a spur to their interest and work in radium therapy. Radium therapist Robert Abbe, for example, said in 1904 that "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 newspapers are occasionally ahead of them."[120] Just ten years later, however, Abbe told another medical audience that "the enormously exaggerated newspaper claims of [radium's] power to destroy disease . . . have justly filled your minds with doubt and disbelief."[121] Breathless newspaper stories on the therapeutic potentials of radium generated interest among some physicians and patients, but also created a strongly skeptical atmosphere amongst the medical community as a whole.[122]

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119 M.A. Cleaves, "Radium: With a Preliminary Note on Radium Rays in the Treatment of Cancer," *Medical Record* 64 (1903): 601–606. Quoted in Jesse N. Aronowitz, Shoshana V. Aronowitz, and Roger F. Robinson, "Classics in Brachytherapy: Margaret Cleaves Introduces Gynecologic Brachytherapy," *Brachytherapy* 6 (2007): 293–297.

120 Robert Abbe, "Radium and Radioactivity," *Yale Medical Journal* (June 1904): 1. His last name is variously reported as Abbe and Abbé, and am using Abbe as most of his publications and references to him spell it this way. There is also no accent in his signature on a letter sent to Howard Kelly in 1913: Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes, Box 7, Radium Correspondence—1913 folder, letter of December 18, 1913.

121 Robert Abbe, "The Efficiency of Radium in Surgery," *Ohio State Medical Journal* (August 1914): 461–465.

122 Pioneering radium therapist Howard Kelly noted this skepticism as well: "A curious shock connected with the early days of our ray therapy was the attitude of the profession at large, which would consign everything connected with radium to the realm of quackery. My distinguished friend, E. M. of Philadelphia unhesitatingly so labelled it; even convincing proofs of [sic] no avail in some instances. For example, C. W., who appeared here from New York expressly to investigate, was shown cases and a large photographic album full of pictures of patients before and after treatments, expressed himself as greatly interested and satisfied, but on his return he declared that radium was of no use at all. Such instances might be multiplied." From a letter of April 11, 1932 from Kelly to Joseph Bloodgood, Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes, Box 7, Radium Correspondence – 1932 folder.

We can see a clear connection between radium therapy and the radium craze, which began in 1903 and lasted for the better part of the decade, by looking at the number of medical publications on radium from 1900–1910. In 1922, the United States Radium Corporation published a *Bibliography on Radium*, which collected every article the American Institute of Medicine found on radium as it related to therapy.[123] (The *Bibliography* includes foreign publications and authors, which I have excluded from my analysis to give a picture of patterns in American radium therapy work.) There are ninety-seven articles from United States publications listed from 1900–1910, with a sharp spike beginning in 1903, corresponding to the beginning of the radium craze.[124]

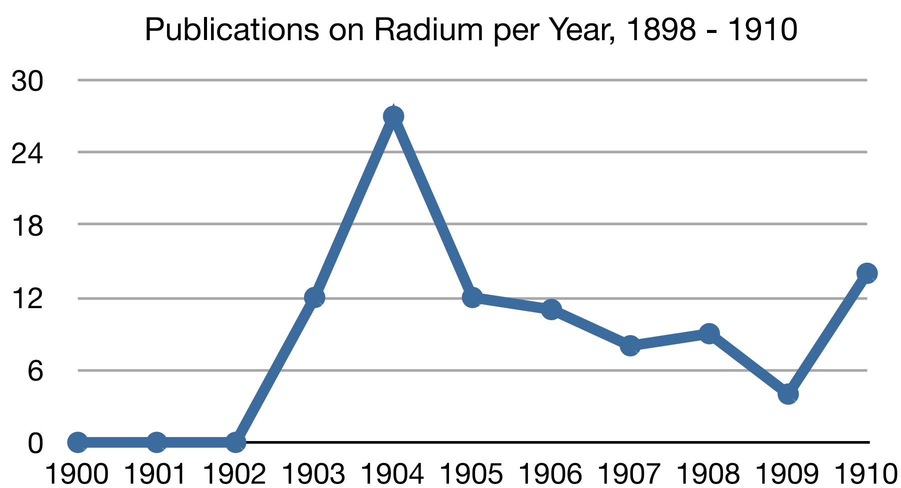

Figure 2.1. Data collected from the *Bibliography on Radium*, excluding foreign authors and journals.

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[123] *Bibliography on Radium: Its Uses and Results from its Discovery Up to January, 1922* (New York: Adams & Grace, 1922). There were two supplements published that collected articles through the end of 1923.

[124] In collecting this data, there was some uncertainty introduced (articles were collected in three categories: year of publication, topic, and journal, and each of these categories gave a different total). The standard error, *s*, introduced by this uncertainty is 4.53. There were additionally 50 foreign articles mistakenly included in those totals, distributed across the 1,232 (average) articles published through 1923. Neither of these sources of uncertainty affect the overall trend of Fig. 2.1 and the spike corresponding to the radium craze.

Radium therapy patients were very familiar with radium because of the radium craze, and had heard of its great therapeutic potentials through newspaper articles. Most had never seen the new element before, unless they had gone to a lecture like one of William Hammer's or had seen it displayed at the 1904 St. Louis World's Fair. Even if they had been to one of these demonstrations, they had never interacted with it in quite the same way as they did during therapy. Even though radium and radioactivity were familiar popular concepts, the direct, physical encounters with radium therapy were distinct and unfamiliar, creating a tension between patient expectations and experiences.[125] Patients received radium therapy for a variety of problems, ranging from cosmetic conditions to deep-seated tumors. Radium seemed to offer a painless, scar-free method for removing acne, birthmarks, and other dermatological problems; it also shrank many tumors, apparently causing them to be replaced with healthy tissue. Sometimes interested physicians suggested the use of radium therapy to patients, other times it was initiated at the request of the patient, who had heard of its effects in the popular press. Some patients demanded a referral or that their physician acquire some radium, and a few wealthy ones purchased radium for themselves.[126] Some patients with inoperable cancers received radium therapy as a last resort, or as a palliative measure because radium was found to have a marked pain-reducing effect. For some patients who refused surgery,

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[125] Matthew Lavine, *The First Atomic Age: Scientists, Radiations, and the American Public, 1895–1945* (New York: Palgrave Macmillan, 2013).

[126] Robert Abbe stated in 1914 that he had had doctors "come to me and say, 'Where can I get radium, $100 or $200 worth? My patients demand it and I want to use it.'" This was not a new situation in 1914. In the Hammer collection are letters to the lecturer from both physicians and patients asking if he might loan them some radium or recommend where they might buy some. *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H.J. Res. 185 and 186*, 63rd Congress, 2nd Session (January 19–28, 1914): 23; William J. Hammer Collection of the Archives of the National Museum of American History.

unwilling to accept its risks, radium therapy offered an alternative that seemed better than no therapy at all.

Generalizing about patient experiences with radium therapy in this early period is difficult, since there was a wide variety of techniques and dosages used. Many of the patients were cancer patients, and most were being treated for conditions that could not be treated by other means or that could only be treated by disfiguring surgery. In a rare introspective moment in the medical literature, physician Thomas Cullen remembered why he decided to refer an inoperable cancer patient to radium therapist Curtis Burnam:

> The patient had a quaint little girl of four who was wrapped up in her mother, and I could not get away from the thought of the tragedy in store for the child. Grasping at a straw I rang up my friend Burnam. ... If the patient remains well say for a year, how much do you think that means to her little daughter and to the family?[127]

This referral was in 1917, after radium therapy was better established and accepted as a treatment for cancer, but Cullen's sentiment was very likely shared by radium therapists, and physicians referring patients to them, in this early period. Some patients, also, would "grasp at straws" if they were told their condition was beyond the help of surgery, asking their physicians for treatment with radium or referral to a radium therapist; encouraged in large part by the media's contagious optimism for the possibilities of radium therapy.

Radium was so popular in this period, and radium therapy so often in the news, that two New York City physicians attempted to cash in on the new therapy without actually having any radium. They prepared so-called radium solutions, that contained no radium, that they sold to patients as drinks and administered by injection in their clinic. Their fraud was quickly discovered and the "radium swindle" was widely reported. It is

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[127] Thomas S. Cullen, "America's Place in the Surgery of the World," *Surgery, Gynecology, and Obstetrics* 25 (1917): 376–390, reprinted in *Radium* 10 No. 2 (November 1917).

unknown how much money they made overall before they were found out, but they were paid $10,000 by one patient alone. They pled guilty to grand larceny and lost their medical licenses.[128] This episode demonstrates radium therapy's popular appeal and its lack of professional identity. Practically, the only requirement for a physician to identify as a radium therapist was the possession of radium—and the two physicians involved with the radium swindle were willing to take their chances on not meeting that requirement.

Radium therapy, in this period and afterwards, could be divided into two categories: external and internal therapy. External therapy was the external application of radium salts in tubes, toiles, plasters, etc., while internal therapy consisted of the inhalation, ingestion, or injection of radioactivity. There were some physicians who experimented in both regimes, but most concentrated on one or the other. The most well-known internal radium therapist in this period was William Morton. Morton, professor of electrotherapeutics and diseases of the mind and nervous system at the New York Post-Graduate Medical School and Hospital, had experience using X-rays for diagnosis and

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128 "Radium Cure Swindle Charged to Physicians," *New York Times* January 24, 1905: 1; "Radium Curists Sentenced," *New York Times* March 24, 1905: 16. Another *Times* article quoted one of their patients at length: "I was in splendid health two years ago, when a dapper young fellow dropped into the shop and suggested insuring my life. In about a week he called again and I made an application. The solicitor reported that I seemed threatened with Bright's disease, but it was not so serious that after medical care I could not pass the examination. He told me of Dr. Kane and Dr. Hale [the radium swindlers]. I called on them, and they gave me an alarming diagnosis. They gave me pills, and I failed rapidly. Analysis showed they contained a good deal of strychnine. When I was at my worst they said that I ought to be treated with radium. I wanted to live to make back part of the money I had already spent with them. Then they suggested an examination which they said would need the services of a chemist and a surgeon and take a week. As I had seen the same examination performed in the hospitals in a very few minutes I began to suspect my physicians and communicated with the County Medical Society." "'Radium' Doctors Held," *New York Times* January 25, 1905: 16.

therapy.[129] He conceived of a therapy combining radioactivity and X-rays to bring light to internal organs, that he called "liquid sunshine therapy." If a few hours' sunbathing was good for health, he reasoned, surely light would also promote general health and heal internal ailments if introduced inside the body. Modern science had presented a way in achieving this for the first time.

Morton's liquid sunshine therapy consisted of giving patients a fluorescent solution to drink, such as quinine, and then exposing them to X-rays or radium. In some cases the fluorescent solution had previously been exposed to radium, which imparted radioactivity to it. The external action of the X-rays or radium, he claimed, would cause the fluorescent substance to glow, bathing the body in light from the inside. If the solution was radioactive, he believed the healthful glow would be greater. In 1903, he stated that for over a year he had treated "nearly all" his cancer patients with this therapy.[130] He had radium of 3,000 and 7,000 "luminosity," by which he presumably meant activity.[131] Speaking at the MIT Sunshine Dinner, Morton cautioned the audience that physicians "will need to use the utmost discretion" when deciding to give radioactive solutions to patients.[132] Morton, however, was generally perceived as a quack by the medical community because of his self-promotion: seeking attention from the press was

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[129] Morton was a well-known electrotherapist, and son of William T. G. Morton, who is identified with the first use of ether as an anesthetic. Before working as a electrotherapist, specializing in nervous diseases, in New York City in the 1880's, he trained at Harvard University and in Vienna.

[130] William James Morton, "Treatment of Cancer by the X-Ray, With Remarks on the Use of Radium," *Internal Journal of Surgery* 16 No. 10 (October 1903): 292.

[131] Ibid. The strength of radium at the time was measured as an activity with reference to the radioactivity of uranium, which was set to a value of 1: so radium salts with an activity of 7,000 were 7,000 times as active as the same weight of uranium.

[132] "To Make Luminous Drinks From Radium," *New York Times*, January 14, 1904.

anathema to the code of conduct for professional physicians. Dr. King at the Flower Hospital, also in New York City, staged a public refutation of Morton's liquid sunshine therapy early in 1905. He gave the therapy to four lab animals, and when their drawn blood failed to be fluorescent, he declared liquid sunshine to be "moonshine."[133]

This did not dim interest in internal radium therapy, however. Physicians continued their trials of radium, internally and externally, in the treatment of a wide variety of ailments. In the public mind, radium therapy was most closely associated with the treatment of cancer.[134] In the 1910's, there were 75,000 deaths from cancer per year in America. And by the 1920s, cancer and heart disease had replaced tuberculosis as the leading cause of death.[135] Radium therapy was a simple, non-invasive procedure at a time when the only accepted cancer treatment was surgery. Many physicians believed that, fearing the potential dangers and mutilations of surgery, patients might put off consulting their doctors until their cancer was in an advanced stage. Some radium therapists hoped that the existence of the much less frightening alternative of radium therapy might encourage patients to visit their doctors sooner.[136] These patients might then undergo surgery, if it was deemed the best treatment, but radium therapy would still

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133 "Liquid Sunshine Called Moonshine," *New York Herald,* May 9, 1905.

134 Howard Kelly, in Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914, 3.

135 Barbara Clow, *Negotiating Disease: Power and Cancer Care, 1900–1950* (Montreal and Kingston: McGill-Queen's University Press, 2001): 40.

136 Francis Williams, for example, voiced this opinion in 1908, and mentioned that "it is interesting to note that surgeons and their relatives have come for this painless treatment rather than submit to operation." "Early Treatment of Some Superficial Cancers, Especially Epitheliomas, By Pure Radium Bromid Rather than Operation or X-rays," *JAMA* 51 (1908): 896.

have done a service simply by encouraging the patient to seek treatment earlier, resulting in a better prognosis.

For patients who did receive radium therapy in this experimental period, there was no shared consensus among radium therapists about appropriate treatment levels. Rather, individual treatment plans were highly dependent upon the radium therapist. Among those focusing on external applications, physicians employed different amounts of radium (always in milligrams) of varying strengths (from 10,000 to 300,000 activity, compared with uranium) for times ranging from fractions of a minute to several hours.[137] One physician found good results with the admittedly "little unusual" method of leaving radium in place overnight for at least ten consecutive months.[138] Another physician, experimenting with radium therapy in 1903, would leave the radium on a cancer patient's cheek until the burning pain "became unendurable."[139] To further complicate matters, it was not standard practice to specify the weight, activity, and exposure time of the radium employed when reporting results. All three were needed for reproducible results, but

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137 For example, Max Einhorn was using 250 mg of radium of 20,000 activity for 1/2–1 hour, whereas Francis Williams employed 50–100 mg for 1/2–4 minutes. Max Einhorn, "Radium Treatment of Cancer of the Esophagus," *JAMA (*July 1, 1905): 8–9. Williams, "Early Treatment of Some Superficial Cancers," *JAMA* 51 (1908): 894–897.

138 Alfred C. Haven, "Will Radium Cure Cancer? A Case," *JAMA* 49 (1907): 2085–6.

139 The patient was his uncle, whose (mouth?) cancer, as reported in the *New York Times*, "could only be cured by cutting half the patient's head away." In the course of treatment, "after a very short time Mr. Hoffman [the patient] complained of a burning sensation in the cheek, which would become unendurable after about forty minutes. The tube would then be removed and put away for several hours." This radium was on loan from William Hammer; the physician, William Van den Burg, also had a stronger sample of radium, which the patient later brought with him for a period of home treatments. "Radium as a Cancer Cure," *New York Times* (December 30, 1903).

radium therapy was still so idiosyncratic that this was not recognized or considered important at the time.[140]

It would have been impossible for most radium therapists to reliably report the strength of the radium salts they used, because most physicians had no way of checking that the activity quoted to them when they purchased their radium sample was its actual activity. Production of radium was not standardized, and many early radium therapists complained that German radium salts were weaker than French radium salts sold as the same strength. It was later found that in many cases there were serious discrepancies between the activity quoted by sellers and the actual activity.[141] This uncertainty in activity notwithstanding, physicians used different radium samples or exposure times, even in the treatment of one patient, and did not find it relevant to report these variations when publishing on their experiences. There was a general belief that individual clinical judgment ought to dictate a physician's treatment decisions. A radium therapist might sketch his method, and then be explicit in his results, understanding that readers of his

[140] Factors including shielding of the radium, distance from the target, and a pathological study of the tumor in cancer cases are also necessary for a complete report, but this was not realized until later. It was generally understood in this period that strength and time influenced the efficacy of a therapy.

[141] In addition to the personal recollections of some physicians, we have the testimony of Charles Viol to the House Committee on Mines and Mining in 1914. He told the committee that "I have talked to the man in charge of the measurement work at the Bureau of Standards, and he has found that ... the common experience ... [about ten years ago, was] that invariably these preparations ... were not what they claimed they were; they did not contain the radium element." Speaking on behalf of his employer, the largest American radium producing company at the time, Viol is very likely exaggerating, but taking this into account it seems safe to conclude that many early adopters of radium therapy, at a time when the production of radium was still in its infancy, had weaker radium salts than they thought. *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H.J. Res. 185 and 186*, 63rd Congress, 2nd Session (January 19–28, 1914) (testimony of Charles H. Viol, January 22).

report would fold this information into what they already understood from their own trials.[142]

Public faith in physicians was generally high during this period, in part because of medicine's growing association with laboratory science and the respect accorded to scientists.[143] The idea of scientific medicine involved more than the transfer of scientific discoveries into the clinic; it also described the ideal of making the practice of medicine itself more scientific, more rational.[144] Both of these aspects came into play with radium therapy. It was a challenge for radium therapists to present their treatments as scientific and rational because cancer, which for most formed the bulk of their cases, was not well understood, nor was the process by which radium attacked cancer cells. Additionally, as discussed earlier, among physicians using radium therapy there was no consensus on dosage, or even on how dosage ought to be reported in the literature.

One significant development in technique in this period was afterloading, or interstitial application. By inserting a trocar needle directly into a tumor, radium could be

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[142] This was consistent with therapeutic practice of the time and with their understanding of scientific medicine. As Harry Marks argues in *The Progress of Experiment,* "Diagnosis and treatment—the 'work' of clinical practice—were understood as exercises in scientific reasoning, akin to the formulation and testing of experimental hypotheses. In an era when diagnostic acumen was the accepted measure of the accomplished practitioner, reformers often presented therapeutic decisions as problems in applied diagnosis: study the patient carefully, reason methodically, arrive at a correct diagnosis, and the therapeutic problem is solved." Harry M. Marks, *The Progress of Experiment: Science and Therapeutic Reform in the United States, 1900–1990* (Cambridge: Cambridge University Press, 2000).

[143] For more, see chapter three, "Science and the Ascent of the Experts," in Barbara Ehrenreich and Deirdre English, *For Her Own Good: 150 Years' of the Experts' Advice to Women* (New York: Anchor Books, 1978); Marks, *The Progress of Experiment*; and Carolyn Thomas de la Peña, *The Body Electric: How Strange Machines Built the Modern American* (New York: New York University Press, 2003).

[144] Harry M. Marks discusses what was needed for a therapy to be considered "rational" in this period in *The Progress of Experiment: Science and Therapeutic Reform in the United States, 1900–1990* (Cambridge: Cambridge University Press, 1997).

"afterloaded" through it into the tumor, thereby maximizing the amount of radiation delivered to it. Before this technique was introduced, local applications of radium salts were exclusively external, which by necessity irradiated any healthy tissues that may have been present between the radium and the cancerous or diseased cells. German physician Hermann Strebel first proposed afterloading in 1903, but it did not receive much attention until pioneering American radium therapist Robert Abbe published on it in 1906.[145]

In this early period, radium was understood to present some dangers, mainly skin burns similar to those produced by X-rays. Radium therapists were learning the horrible consequences of prolonged unprotected exposure to X-rays as many therapists and researchers lost fingers, hands, and in some cases their lives, because of the radiation.[146] The conventional wisdom of the time was that the burns from radium were, generally, less dangerous than those from X-rays—perhaps because radium workers were not being "martyred" the way roentgenologists were—but many radium therapy patients were burned, especially in this early period, and in some cases seriously. There were cases of patients dying from their radium burns.[147] However, most radium burns healed quickly,

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[145] For more, see, for example, R. F. Mould, "Priority for Radium Therapy of Benign Conditions and Cancer," *Current Oncology* 14 No. 3 (June, 2007): 118–122.

[146] The ability of radioactivity to cause mutations was not demonstrated until 1926 by Hermann Muller; neither was it understood in this early period that radium, chemically similar to calcium, if introduced into the body is plated into the bones where it continually emits radiation. Rebecca Herzig studies the rhetoric of labeling, and self-identification, of injured roentgenologists as "martyrs" in "In the Name of Science: Suffering, Sacrifice, and the Formation of American Roentgenology," *American Quarterly* 53 (2001): 563–589.

[147] For example, in the discussion of a paper given at the 1914 meeting of the American Medical Association, Kansas City physician Richard Sutton recounts the painful death of a cancer patient in his care who had been "severely burned" in the course of radium therapy given by another (unnamed) physician. Arthur F. Holding, "The Relative Value of Radium in Dermatology," *JAMA* 63 (1914): 741–743.

leaving no scar; at worst, the skin remained reddened.[148] Radium was generally considered to be safe by early radium therapists, who often relied on the appearance of burns to monitor the course of their treatments.

It was empirical observations, like the monitoring of burns, that largely guided radium therapy in this experimental period. Radium therapy was also influenced by the radium craze, which attracted some patients and physicians to the new therapy. Dosage and methodology varied from practitioner to practitioner in this experimental period—but as we will see in the following sections, connections with physicists and physics knowledge were universally important to these early adopters.

Radioactive Networks

To acquire radium, an interested physician needed to connect with scientific networks of physicists and chemists working with radium. The medical community had yet to be convinced of the definite value of this new therapy, and medical connections alone were generally insufficient to allow a practitioner to borrow or purchase radium. Electrical engineer and radium lecturer William Hammer was an important node in the radioactive networks that could supply radium to physicians, and he was also one of the few scientists who was directly involved with treatments. This section ends with an analysis of some of the early adopters of radium therapy using their experiences as a case study of how radium therapies relied on physics and physicists. Robert Abbe, who

[148] This was, of course, the best understanding at the time; now we understand that in addition to this short-term danger of burns, prolonged or repeated exposures greatly increase the risk of cancer. In this first decade, not enough time had passed for cancers caused by exposure to radium to appear; and it took several decades for research to confirm the carcinogenic nature of ionizing radiation like radioactivity.

experimented with radium's physical and physiological effects, receives special attention. Radioactive networks provided radium therapists with prestige, advice, and, critically, radium itself.

Scientists were aware of the therapeutic potentials of radium, and at the height of the radium craze some were moved to comment publicly on it. Frederick Soddy and Alexander Graham Bell both published on the subject in 1903. Soddy encouraged physicians to experiment with the emanations from radium and thorium in the treatment of consumption in an article in the *British Medical Journal*, reasoning that the inhalation of these radioactive gases might allow the illness to be targeted in the patient's lungs.[149] Bell wrote to a Washington, D.C. physician suggesting another way of using radium therapeutically; his letter and the physician's brief but optimistic response were published as a letter to the editor in *Nature*. Bell pointed out that one of the drawbacks of using Crookes tubes in the treatment of cancer was that the X-rays produced can only reach tumors relatively close to the skin. Might not radium, Bell reasoned, be sealed up in a small glass tube and the tube then inserted surgically into the center of a tumor? He sent these letters to the editor of *Nature* in the hopes that the idea might reach someone

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[149] Soddy was particularly enthusiastic about the potential of thorium emanation over radium emanation. Thorium was much less expensive than radium and has a much shorter half-life, but it was also much less radioactive, so of little use in therapy; however, as it was the thorium emanation that was important in Soddy's proposed therapy. He argued that the half-life (and therefore the rate of production of the emanation) was more important than the activity and thus the much cheaper radioelement might be of use to medicine. Soddy, "Radium: A Method of Applying the Rays of Radium and Thorium to the Treatment of Consumption." Within a year an article appeared in the same journal reporting on two cases of tuberculosis treated with Soddy's suggested therapy (with some apparent success, though the author states that it was too early to say for sure and he has no direct evidence that the thorium emanation had anything to do with his patients' improved conditions). Gordon Sharp, "Two Cases of Lung Disease Treated with the Emanations from Thorium Nitrate," *British Medical Journal* (March 19, 1904): 654–655.

interested in experimenting along these lines.[150] The suggestions of Soddy and Bell illustrate not only the popularity of radium but also the interest in its therapeutic potentials on the part of scientists uninvolved with medical matters.[151]

The interest of leading scientists like Soddy and Bell in radium therapy also raised its public visibility and prestige. In the first decade of the twentieth century, science enjoyed a large amount of public and professional prestige, and one of the benefits of the medical profession's shift to emphasize "scientific medicine" was sharing some of this prestige.[152] What were then known as physical therapies—therapies based on physics like radium therapy, X-ray therapy, and electrotherapy—were especially well positioned to borrow prestige from science.[153] For radium therapy in this experimental period, this borrowed prestige could not, on its own, overcome the natural skepticism of the medical profession, but did much to endow radium therapists with expertise in the eyes of potential patients.

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150 "Radium and Cancer," *Nature* (August 6, 1903): 320. Bell's idea did not lead to immediate research along these lines; but this form of therapy, now known as brachytherapy, was eventually adopted with radium salts and is still used today with radioactive isotopes.

151 Uninvolved for the time being, at least; in a 1909 article Soddy stated that he had prepared a thin radium applicator at the request of a physician. Frederick Soddy, "The Therapeutic Applications of Radium: Methods and Results," *British Medical Journal* (March 27, 1909): 797.

152 As Joan Austoker argues, "despite the fact that most science remained essentially divorced from practical relevance [to medicine in American and Britain], its professional value and prestige was considerable. What was significant, therefore, was not the incorporation of scientific ideas into medicine, but a conception of science as a powerful and compelling means of conferring 'expert status' upon medicine." Joan Austoker, *A History of the Imperial Cancer Research Fund, 1902–1986* (Oxford: Oxford University Press, 1988). For the American public, "science" included laboratory sciences as well as field and social sciences, and all of these were respected. Within medicine, laboratory sciences in particular carried authority; see Robert E. Kohler, *From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline* (Cambridge: Cambridge University Press, 1982).

153 Vivien Hamilton has argued about the rhetorical importance of physics to X-ray therapy; for example, "X-Ray Safety," talk at 2012 History of Science Society / Philosophy of Science Association meeting in San Diego, California, November 15–18, 2012.

These rhetorical connections with physics were important for the young field of radium therapy, but they were not the only way radium therapists situated themselves within radioactive networks. It was often not a straightforward process for a physician to acquire radium salts. One needed the right connections, as is demonstrated by the editorial response to a 1903 letter in the *Journal of the American Medical Association*, which was the most widely read and respected American medical journal. A Missouri physician wrote the journal asking for help acquiring a small sample of radium, and the editor was cautious: "Radium is hardly yet a commercial product, and samples are obtained more by favor than otherwise. It is thus far more of a scientific curiosity than anything else."[154] It is evident from this response that the general medical community was skeptical of radium therapy, and that the editors of *JAMA* were unwilling or unprepared to recommend any radium suppliers to their readership. Personal connections, more than professional status, were needed to acquire radium during the height of the radium craze.

To acquire radium in the first years after its discovery, one had to have a personal connection with the Curies and some financial means. However, when the radium craze hit America in 1903, it was already possible to buy radium through a few brokers. Electrical engineer and popular lecturer William Hammer recommended Eimer & Amend, who imported French radium, to most who asked. H. Lieber & Co., also in New York City, imported radium as well, from Germany. It was also possible to buy radium

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[154] "Radium," *JAMA* 41 (1903): 324.

directly from Harrington Bros. in London, the de Haën company in Seelze, Germany, and from Friedrich Giesel in Brunswick, Germany.[155]

Within a few years, radium therapists generally agreed that Parisian radium was of more reliable quality and strength than German radium. In Paris, the Curies were working closely with the *Societé Centrale des Produits Chimique*. As they continued their work with radium, the processes required more space and attention than the two of them could provide on their own in the *hangar* in which they worked in Paris. The *Societé Centrale* did the initial purification of their pitchblende and worked with the Curies in radium production. The *Societé* soon began working with the company *Sels de Radium*, which was also run by the industrialist Armet de Lisle.[156] *Sels de Radium* began sales of radium salts in 1904.[157] Acquisition of radium was made more difficult in 1907 when Austria, which had been providing a large percentage of the world's pitchblende, embargoed it, preferring to keep this radium-bearing ore at home so that its products could be used domestically.[158]

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155 Giesel was among the first to produce radium on a commercial scale, and he also experiments with radium. R.F. Robison discusses Giesel's work in detail in "The Radium 'Business' of Providing Medical Sources," *Current Oncology* 3 (1996): 156–162.

156 For a detailed investigation of the crucial connections between the Curie research laboratory and industrial-scale production facilities, see Soraya Boudia, "The Curie Laboratory: Radioactivity and Metrology," *History and Technology* 13 (1997): 249–265.

157 Thomas F. V. Curran, *Carnotite: The Principal Source of Radium* (New York: Curran & Hudson, 1913): 20, Series 3, Box 64, Folder 5, William J. Hammer Collection of the Archives of the National Museum of American History (hereafter denoted as WHC). Maria Rentetzi, *Trafficking Materials and Gendered Experimental Practices: Radium Research in Early 20th Century Vienna* (New York: Columbia University Press, 2008): 41. See also Xavier Roqué, "Marie Curie and the Radium Industry: A Preliminary Sketch," *History and Technology* 13 (1997): 267–291.

158 In 1914, the United States briefly considered nationalizing its radium ores. That debate and its implications are discussed in chapter four.

All radium salts in this first decade had to be imported to America. Radium was purified from pitchblende or carnotite; pitchblende is generally richer in radium, but after the Austrian embargo, American carnotite became the best source for the European producers, who imported the American ore to be purified into radium salts.[159] Only one American entrepreneur experimented with radium production at the height of the radium craze: Stephen T. Lockwood, who founded the Carnotite Chemical Reduction Plant outside Buffalo, New York in 1903. Lockwood began experimental extraction of radioactive ores in 1902, and corresponded with Pierre Curie. The plant was run until 1908, processing Utah uranium ores into uranium and vanadium end-products. With the assistance of physicist George Pegram at Columbia and Yale chemist Bertram Boltwood, Lockwood determined that he could not refine radium salts and make a profit.[160]

Thus, the huge majority of radium produced in this early period was refined in Europe, and Americans who wished to purchase radium needed to enter the radioactive networks that had access to European producers. New York City physicians Margaret Cleaves, a pioneer in X-ray and radium therapy, and Henry Janeway, who went on to be one of the most influential radium therapists in the next decade, both wrote to Hammer in the fall of 1903 to request his help in attaining radium. Other physicians reached out to physicist acquaintances or to local university physicists, asking to borrow their samples

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[159] R. F. Robison estimates around 20 grams of radium was produced in Europe from American ores from 1900–1913. "The Radium 'Business' of Providing Medical Sources," 158.

[160] Refining radium was an expensive prospect because tons of ore had to be laboriously chemically processed to isolate grams of radium salts. Some of the radium Lockwood purified during the course of his experiments went to the 1904 St. Louis World's Fair, Columbia University, and the Smithsonian. Edward R. Landa, "A Brief History of the American Radium Industry and its Ties to the Scientific Community of the Early Twentieth Century," *Environment International* 19 (1993): 503–508.

of radium or for advice on where best to buy their own. Many physicians were able to successfully engage with radioactive networks to acquire radium. At least seven such physicians appear in the Hammer Collection; and the *Indianapolis Sentinel* in 1904 counted more than fifteen in New York alone.[161]

At rare times in this period, scientists were directly involved with the clinical work of radium therapy. One of these scientists was William Hammer, the electrical engineer and public lecturer who was the focus of chapter one. In 1903, Hammer proposed three methods of internal radium therapy that received some press attention. The first two methods are fairly straightforward, using radium solutions against bacteria and prescribing radium pills, powders, or liquid medicines for gastrointestinal problems. The third method was more complicated, and demonstrated Hammer's interest in electricity. He proposed the injection of radium solution followed by cataphoresis—the external application of an electrical current to draw the solution to the application location to concentrate the radioactivity in a local treatment.[162] Although Hammer loaned radium to several New York City physicians, and collaborated with a few directly in their radium therapy, it is unclear if he was successful in convincing any to try cataphoresis with radium. The only mention of cataphoresis in his correspondence preserved in the

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161 "Diptheria is Cured by Radium," *Indianapolis Sentinel*, January 19, 1904.

162 Cataphoresis is electrophoresis of positively charged particles; presumably Hammer was expecting the positively charged alpha particles to be drawn to the site of application. Hammer's theories are most clearly laid out in a letter of November 14, 1903, Series 1, Box 17, folder 6, WHC. Ever the entrepreneur, Hammer was distressed that William Morton and Samuel Tracy were claiming priority for the idea of internally applied radioactive solutions, and discussed the matter with a patent attorney, though nothing came of it. Letter of February 19, 1904 to Mr. Frederick W. Barker, Series 1, Box 3, Folder 10, WHC.

Smithsonian's collection is in a letter to physician William King where he pleads that it be tried.[163]

King was dean of the faculty of the New York Homeopathic College and head of the electrotherapy clinic, so he was an excellent candidate for Hammer's suggestion. Hammer provided King with radioactive water, which King enthusiastically used in the treatment of ailments such as diphtheria and stomach cancer. Hammer had previously tested radioactive water on himself and his family; he sent a bottle to his sister, for example, to help with some unknown ailment.[164] Hammer also worked with other physicians in the hospital associated with the Homeopathic College's Flower Hospital, beginning in 1903.[165] Homeopathy was looked down upon by allopathic physicians, but was an accepted alternative in the medical marketplace for patients. Starting at the turn of the century, American homeopaths, like allopaths, began to incorporate the ideals of scientific medicine into their curricula and methodology.[166] It is interesting that Hammer found a receptive audience for some of his ideas about internal radium therapy in a homeopathic hospital; perhaps these doctors, and their patients, already involved with therapy outside of mainstream medicine, were more receptive to trying a modern, experimental therapy. Hammer provided a total of four hospitals with radioactive water.

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163 Letter of December 22, 1903 to Dr. William H. King, Series 1, Box 3, Folder 10, WHC.

164 Letter of April 20, 1904 to Percy Troutman, Series 1, Box 3, Folder 10, WHC.

165 The Homeopathic College was founded in 1890, and is now the New York Medical College.

166 Naomi Rogers, "The Proper Place of Homeopathy: Hahnemann Medical College and Hospital in an Age of Scientific Medicine," *The Pennsylvania Magazine of History and Biography* 108 No. 2 (April, 1984): 179–201.

In 1903, Hammer gave a tube of radium to a New York physician, who used it as a treatment of last recourse to treat his uncle's inoperable cancer.[167] Hammer also collaborated with Willy Meyer, a surgeon at Mt. Sinai Hospital, and provided him with radium salts. Mt. Sinai was a teaching hospital, so its physicians were perhaps more open to trying experimental therapies than hospitals whose primary goal was patient care.[168] Hammer and Meyer used radium of 300,000 activity, probably in a very small amount, to treat an axillary cancer. Applying the radium once a day for one minute, they were able to shrink the tumor and lessen the pain, though the patient ultimately died.[169] It may have been this patient who purchased the radium himself and verbally promised the sample to Meyer in the case of his death, though his family gave the radium to another physician. Meyer's loss of this strong sample caused Hammer to hurriedly ask for more radium from his Paris supplier.[170]

One of Hammer's forays into radium therapy received massive amounts of press attention: his collaboration with Amon Jenkins of the Marine Hospital in the treatment, and claimed cure, of a young blind girl. Tillie Spitznadel was eleven in 1903, and had been blinded by meningitis when she was three. There were two events that Jenkins and Hammer took as precedents. First, there had been recent highly publicized reports that a

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[167] The physician's uncle probably had a mouth cancer; it is not explicitly stated in the *Times* article reporting on the treatment, but the article states that "physicians in consultation declared that the cancer could only be cured by cutting half the patient's head away." "Radium as a Cancer Cure," *New York Times* (December 30, 1903).

[168] In *Learning to Heal*, Kenneth Ludmerer argues that teaching hospitals prioritized education over patient care, as compared with hospitals totally dedicated to patient care. Kenneth M. Ludmerer, *Learning to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care* (Oxford: Oxford University Press, 1999).

[169] John Inglis, "Radium and Radiant Energy," *JAMA* 42 (1904): 373.

[170] Letter of October 15, 1903 to Mr. P. Boulay, Series 1, Box 2, Folder 8, WHC.

Dr. London of St. Petersburg, Russia had had some success in reversing blindness. Second, when Hammer was in Italy in 1902, he visited an exhibition in Naples featuring an electric torpedo, a fish which produces an electric charge like an electric eel can. Having his radium with him, after his party had all touched the fish and received shocks, he placed six tubes of radium on the ray and left them there for twenty minutes. After removing the radium, the torpedo was unable to produce any shocks. "Now, I am prepared to admit that the fish might have been 'entirely out of shocks,'" he wrote, but he wondered "whether the radium did not affect the ability of the fish to give off electric shocks, perhaps producing a partial paralysis."[171] He was encouraged in this conclusion after reading of Pierre Curie's experiments in which he paralyzed mice and guinea pigs with radium. Hammer speculated in his lectures that sleeping with radium under one's pillow might cause paralysis of the brain. As with homeopathic treatments it was reasoned that if something were dangerous in large amounts it would have an opposite beneficial effect in small doses, Hammer reasoned that if radium had the power of paralysis, perhaps its application could reverse the "paralysis" of Tillie's optic nerve.[172]

Hammer and Jenkins treated Tillie in Hammer's home laboratory, combining X-rays and radium in the hope that they would work together. Hammer speculated that

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[171] William Hammer, "Radium and Other Radioactive Substances with a Consideration of Phosphorescent and Fluorescent Substances. The Properties and Applications of Selenium and the Treatment of Disease by the Ultra Violet Light," *Transaction of the American Institute of Electrical Engineers* 20 No. 5 (May, 1903): 568–9. Hammer was eager to repeat this experiment, and so wrote to an Italian contact asking if he might send him some torpedoes; the Milanese engineer responded "About torpedos [sic] I should be very puzzled in sending them over as I do not know what food they would require, and perhaps travelling [sic] on a steamship they would be eager to be sea sick." Letter of November 28, 1903 from Guido Semenza, Series 1, Box 5, Folder 11, WHC.

[172] Letter of October 6, 1903 to Mr. W. H. Dillingham, Series 1, Box 3, Folder 10, WHC.

"possibly the X-Rays had carried the radio-active properties with them, or that possibly the two sets of vibrations, acting in conjunction had produced overtones or higher harmonics, and the necessary periodicity to stimulate the paralyzed optic nerve."[173] Hammer had a fairly good understanding of the science of radioactivity but it is unclear how he understood X-rays acting as a carrier wave or X-rays and radioactivity interfering with each other. It seems likely that he was content to propose those scientific possibilities (however improbable even by the science of the time).

Hammer had accidentally partially blinded himself with radium before starting the therapy, so he and Jenkins took care to limit the exposure time. They placed the radium in a chocolate box and held it to Tillie's eyes, forehead, temples, and nape while exposing her to X-rays, and after several sittings, they reported with great fanfare that her sight had been partially restored and there was hope for a full recovery.[174] The newspapers predictably went wild with reports of this success of biblical proportions. The *New York Sun* describes the miraculous restoration of Tillie's sight occurring on a streetcar while Jenkins was escorting her home. Jenkin's statement that she was correctly pointing out streetlights as they passed them seems, in hindsight, a clear case of confirmation bias produced by his own enthusiasm for the treatment and desire of a child to please the adults who were so concerned with her condition. Within a few days it came out that Tillie's mother had seen no improvement in her daughter's condition; it is unclear how long treatment was continued after this, if at all, though Hammer continued to claim success for months afterward.

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173 Letter of March 15, 1904 to Professor W. F. Hardmann, Series 1, Box 3, Folder 10, WHC.

174 "Made to See with Radium," *New York Sun*, August 23, 1903.

The direct clinical involvement of a scientist like Hammer was a rarity in radium therapy. Generally, physicians who reached out to physicists, who confined their assistance to scientific advice, connections with radium supply networks, and possibly the loan of their radium salts. But an interest in physics and connections with physics networks were not sufficient to start a physician in radium therapy. There was also the issue of cost. All radium was imported into America, and while the price fluctuated greatly, radium was well known to be, per milligram, the most expensive substance on earth. The price depended on the strength of the preparation. A milligram of relatively strong radium salts (tens or hundreds of thousands times stronger than uranium) in this first decade of the twentieth century would, for example, cost a physician over a hundred dollars.[175] In December, 1903, Hammer sent a price list for radium samples that Thomas Edison had requested from him. The radium was priced according to weight and purity, the most expensive sample being one gram of 2% purity for $150 (special to Edison, $120). Six months later, Hammer sent a price list to another correspondent; this list, based on quotes from two U.S. suppliers, priced the radium on weight and activity, the most expensive being 10 milligrams of 1,000,000 activity at $200, which was the strongest radium available at the time.[176]

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[175] A few brief examples of the cost of radium: in their 1904 report on the MIT Sunshine Dinner, the *St. Louis Medical Review* stated that radium cost $15,000 per gram; in 1910 *Popular Mechanics* gives a price of $77,000 per gram. "A Radium Banquet," *St. Louis Medical Review* (March 12, 1904): 170. George E. Light, "The Discovery of Pure Radium by Mme. Curie," *Popular Mechanics* (Novemeber 1910): 637–638.

[176] Letter of December 4, 1903 to Edison, Series 1, Box 3, Folder 10, WHC. $200 in 1904 is comparable to around $4,700 in today's money; $150 to around $3,600. (The Inflation Calcuator, http://www.westegg.com/inflation/.) Radium salts were sold most commonly in glass tubes; de Haën sold its radium preparations stronger than 50,000 in hard rubber containers with mica. De Haën pamphlet "Radio-Active Substances," Series 3 Box 65, Folder 2: Authors D, WHC.

During this early period, however, very weak radium salts were available for purchase at prices within the means of most physicians. In his 1910 book on physical therapies, Sinclair Tousey said that a gram of radium bromide only fifty times stronger than uranium could be bought for only $4 (around $97 in today's money).[177] However, it was recognized by many radium therapists very early on that such weak samples were essentially useless for therapy. In a 1904 address, radium therapist Robert Abbe told his audience that "you may know that the weak radium specimens [around 240 times stronger than uranium] are of little therapeutic use—but are inexpensive."[178] Physicians working with inexpensive radium salts found little success, and either found ways to access stronger samples or gave up on radium therapy.[179]

It is useful to look more closely at a few of the physicians who did not give up on radium therapy to see how they were connected with radioactive networks. The first American physician to use radium therapeutically was Francis Williams, in 1900. Williams' knowledge of physics and personal connection with a physicist were key to this first use. He and his brother-in-law, dentist William Rollins, both had experience with X-rays and were receptive to the therapeutic potential of the new discovery in physics. Williams was a professor at Harvard and had worked with Massachusetts Institute of

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177 Sinclair Tousey, *Medical Electricity and Roentgen Rays with Chapters on Phototherapy and Radium* (Philadelphia: W. B. Saunders, 1910): 1045. The Inflation Calcuator, http://www.westegg.com/inflation/.

178 Robert Abbe, "Radium and Radioactivity," *Yale Medical Journal* (June 1904): 6.

179 Charles Rosenberg discusses the limited financial means of many doctors of this period in *Explaining Epidemics and Other Studies in the History of Medicine* (Cambridge: Cambridge University Press, 1992).

Technology physicist Charles Robert Cross in experimenting with X-rays.[180] In 1900, at the suggestion of University of Pennsylvania physicist George Barker, Rollins loaned part of his small sample of radium to Williams, asking that he use it experimentally with lupus. This first attempt produced no beneficial results as the radium was too weak, but Williams and Rollins continued their work with radium therapy.[181] By 1904, Williams had treated fifty patients, mainly with cases of skin cancer and non-malignant skin conditions, and found that radium had to have an activity of 8,000 (in the units then used, radioactivity was measured against uranium's, which was set to be 1) to be useful therapeutically.[182] We can see the importance of physicists and physics in this first therapeutic use of radium in America—Williams and Rollins worked closely together and they shared an interest in physics and connections with university physicists. Their interest in physics led them to consider radium therapy, and their connections with physicists allowed them to move from consideration to realization.

Another notable early adopters of radium therapy was Robert Abbe—his early work is identified as foundational by later radium therapists.[183] We can see how physics networks were crucial to his adoption of radium therapy.

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180 Hrudaya Nath, "Francis Henry Williams: The Father of Cardiac Fluoroscopy," *American Journal of Roentgenology* 160 (1993): 260.

181 For more, see Ruth and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: The Williams and Wilkins Company, 1969).

182 Francis H. Williams, "A Comparison Between the Medical Uses of the X-Rays and the Rays from the Salts of Radium," *Boston Medical and Surgical Journal* 150 (1904): 206–209.

183 The Brechers count eleven other physicians, in addition to Cleaves and Abbe, who began using radium therapeutically in 1903 or early 1904: *The Rays*, 159.

In 1903, surgeon Robert Abbe purchased his first radium, from Paris. Abbe was a rarity amongst radium therapists in his experimentation with radium; he published results from his plant, animal, and human studies in medical journals. His interest in these studies was mainly the physiological effects of the different forms of radioactivity: what these effects were, if they differed between the three rays, and what explanations there might be for the effects. In 1904 Abbe described his initial work by saying, with considerable understatement, "I have been able to snatch a few hours out of a busy year to look into the matter somewhat from a practical standpoint and, incidentally, to pick up some points on the physics of the subject of radium."[184] It was not unusual for radium therapists to educate themselves on the basics of the physics of radioactivity, but this self-education through laboratory experimentation is completely unique to Abbe.

In 1904, Abbe exposed seeds to radium and found their growth slowed and stunted; radiated ants were "unable to rear their embryos"; and young mice exposed to a strong sample of radium became "dopy," paralyzed, and finally died.[185] In one early case, Abbe treated an ear ulcer by covering half of the ulcer with lead shielding and exposing it to radium, then shielding the other half and exposing it to X-rays, as a way of comparing the two therapies. Both were healing, though X-rays ultimately acted more quickly.[186] In a case of breast cancer, he made for himself an opportunity to study, microscopically, the effect of radium on human tissues. The patient was scheduled for a

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[184] Robert Abbe, "Radium and Radioactivity," *Yale Medical Journal* (June 1904): 1

[185] Ibid., 10–11.

[186] Robert Abbe, "The Subtle Power of Radium," *Transactions of the American Surgical Association* 22 (1904): 255.

mastectomy, and every day for a week before the operation he placed radium tubes on different places on the breast. After the surgery, the tissues were studied pathologically under the microscope; it was found that healthy skin was necrotized by the radium, and tumor cells were killed and in some cases underwent "retrograde change."[187] With his early experimental work, Abbe attempted to better understand both the physics and the physiological effects of radium.

Concluding his article "The Subtle Power of Radium," Robert Abbe summarized the different theories for the physiological action of radium. There had been reports, in the medical literature and in the popular press, of the bactericidal effect of radium, but Abbe concluded that it is "too feeble and inadequate to account for all we have seen."[188] It was well known that radium maintained a temperature several degrees warmer than its surroundings; however, Abbe also discounted the possible physiological effects of radium's heat. One of the most difficult problems in trying to understand radium's effect on cancer cells was that cancer was not well understood. Abbe hypothesized:

> It may not be of germ origin, but merely the erratic and disorderly growth of cells, which have lost their innervation and grow wildly. A regenerating power may be supplied by the so-styled bombardment by particles of radium atoms carrying each its charge of negative electricity. This must be, as yet, speculative.[189]

Another possibility, as Abbe explained, was that the radiation causes tissue inflammation that destroys the most heavily effected cells and sets up a healthy regeneration in others. Drawing an analogy to his plant experiments and to experiments that showed that

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[187] Ibid.: 259.

[188] Abbe, "The Subtle Power of Radium," 260.

[189] Ibid.

irradiated mealworms remained larvae, he suggests that "those malignant cells which have escaped destruction and retrograde change show a striking quiescence, which may mean death of the vital force which makes them malignant. In this connection we cannot fail to be reminded of the seeds which do not grow and the meal-worms which are arrested for an indefinitely long period."[190] This analogy was made by several others, and in this early period the few animal and plant experiments with radium were mostly used only analogically by radium therapists. In 1910, Abbe refined this analogy, arguing that as seeds exposed to radium grew to heights inversely proportional to exposure time, so radium probably acts on cancerous cells.[191] Radium did, however, seem to have a kind of specific action on (at least some) cancer cells. In 1906, French researchers Jean Bergonié and Louis Tribondeau discovered an effect that was named after them, that radium had a stronger effect on young or dividing cells; cancerous cells, generally characterized by rapid division, would therefore be more effected than healthy cells.[192] There was, however, still no physiological understanding of why this might be the case.

Abbe and Williams and Rollins are notable because of their lasting contributions to American radium therapy. Their connections with radioactive networks are illustrative of those all American radium therapists made in this experimental period, however. These networks were crucial for physicians to acquire radium, and also provided advice and prestige.

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[190] Ibid.

[191] Robert Abbe, "Radium's Contributions to Surgery," *JAMA* 55 No. 2 (July 9, 1910): 97–100.

[192] J. Bergonié and L. Tribondeau, "De Quelques Résultats de la Radiotherapie et Essai de Fixation d'une Technique Rationnelle," *Comptes-Rendus des Séances de l'Académie des Sciences* 143 (1906): 983–985.

Understanding the Physics of Radioactivity

Scientific research into radium and radioactivity had implications for radium therapy. The identification of three distinct kinds of rays emitted by radioactive substances meant that radium therapists could select one or two kinds for treatment. Moreover, the discovery of radioactive decay chains demonstrated the necessity of allowing radium salts to age to reach maximum production of the strongest rays. The importance of scientific observations to therapy can be shown by looking at the articles on radium therapy published in the *Journal of the American Medical Association* in this period. This period of American radium therapy was experimental and highly empirical, but discoveries in physics shaped the basic character of the new therapy.

It was in large part through the research of Ernest Rutherford and Paul Villard that it was understood that there were three distinct forms of radioactivity, called alpha, beta, and gamma radiation. Soon afterward, Rutherford and Frederick Soddy established that the process of radioactivity is actually a chemical disintegration, with radioactive elements changing into different elements. In his 1911 *The Chemistry of the Radio-Elements*, Soddy presented the current understanding of radioactive decay chains, the succession of elements resulting from radioactive transmutation.[193] Fig. 2.2 is Soddy's graphical representation of radium's decay chain (a subset of the uranium decay chain). In it we can see the isotopes involved, named for their place in the chain, their half-lives

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[193] Frederick Soddy, *The Chemistry of the Radio-Elements* (London: Longmans, Green and Co., 1911).

(written below the names), and the rays given out by each isotope.[194] Alphas are designated by the Greek letter and by a small circle since it was understood to be a particle, a He^{++} ion. The betas were also understood to be particles, electrons, and are designated in the chart by a smaller, filled-in circle in addition to the Greek letter. Some βs are in parentheses, indicating that they are very low energy and easily absorbed.[195] The wave or particle nature of the gammas was under debate, but for the most part acted as rays and so are unaccompanied by a circle on the chart.[196]

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194 I am being anachronistic with my language here, because it was not until 1913 that Soddy introduced the term isotope, based on this research with radioactivity. See Frederick Soddy, "The Radio-Elements and the Periodic Law," *Chemical News* 107 (1913): 97–99, and Frederick Soddy, "Radioactivity," *Chemical Society Annual Reports* 10 (1913): 262–288.

195 Ibid., 8.

196 Ibid., 7. For more on this debate on the nature of gammas, see the discussion in Bruce R. Wheaton, *The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism* (Cambridge: Cambridge University Press, 1991).

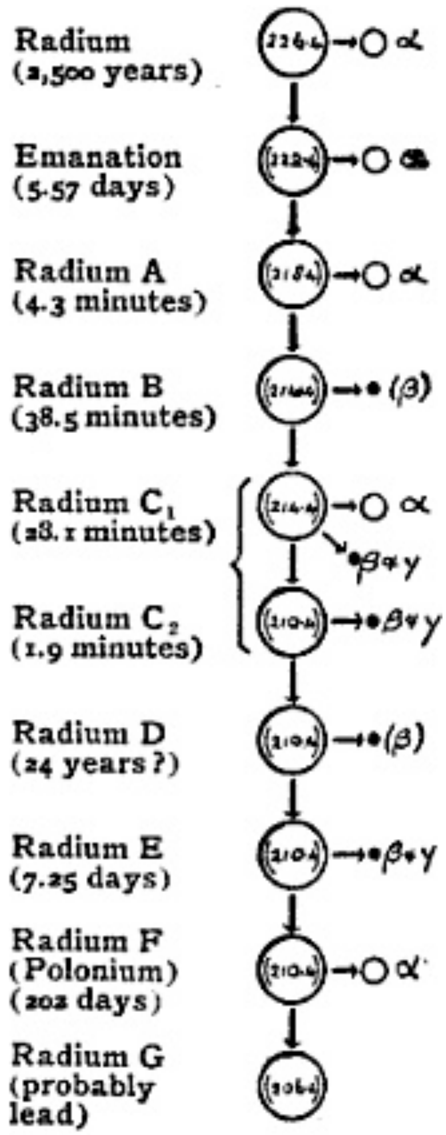

Figure 2.2. Detail from chart at the end of Frederick Soddy's The Chemistry of the Radio-Elements *(London: Longmans, Green and Co., 1911). (The "α" from emanation is smudged; the estimated atomic weights, written inside the isotopes' circles, are illegible at this size but are irrelevant for this discussion.)*

Alphas, betas, and gammas are distinguished by their deflection in a magnetic field and the degree to which they penetrate matter. Fig. 2.3, which shows a sample of radium in a lead block *P* in a magnetic field, illustrates their differences. Alphas are easily absorbed and positively charged; betas are moderately penetrating and negatively charged; and gammas are highly penetrating and uncharged. The differences in penetrating power were important for radium therapy.

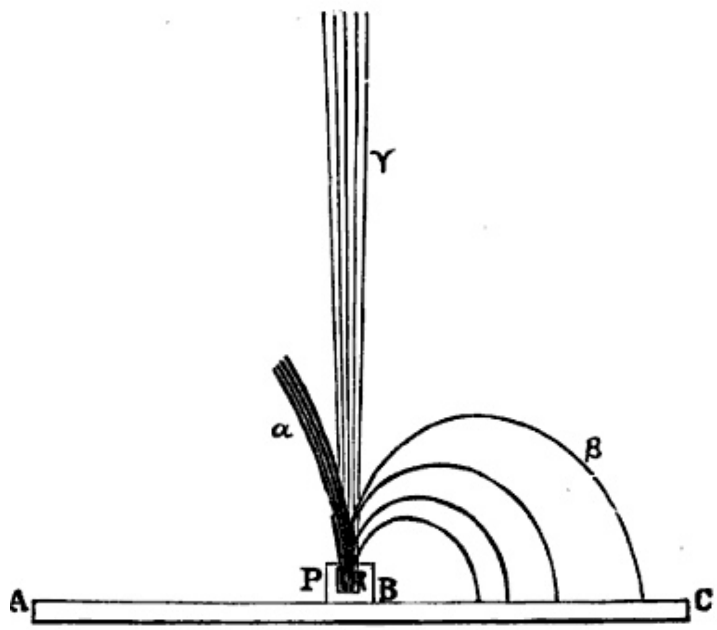

Figure 2.3. From page 33 of Marie Sklodowska Curie, "Radio-Active Substances," (London: Chemical News Office, 1904).

Alphas, because of their low energy and corresponding ease of absorption in matter, are completely absorbed by the first few layers of skin and cannot, for example, reach tumors deeper than that. A radium therapist desiring to target a deeper tumor could introduce a filter between the radium and the skin to absorb alphas and low-energy (soft) betas, thereby allowing the high-energy (hard) betas and gammas to reach the tumor while preventing a skin burn caused by alphas and soft betas.[197] Alternatively, since the majority of the radiation emitted by a preparation of radium salts is in the form of alpha

[197] Filters like this were often made of lead or a similar metal. However, it became apparent that when gamma rays strike metal, they can produce secondary beta radiation (an example of the photoelectric effect), so while the original beta radiation from the radium salts was absorbed by the lead, soft betas were still absorbed by the skin. Learning this from physicists, physicians began adding a layer of rubber or a similar substance after the lead filter, to absorb this secondary radiation.

radiation, a physician using a very weak sample of radium could deliver alphas to the skin while exposing the patient to fewer betas or gammas than would be emitted by a stronger source.[198] There was debate in this first decade about which form of radiation was preferable, and we will look more closely at this debate and its resolution in chapter four.

For those physicians preferring to use gammas and hard betas in therapy, they had to take care to let newly-prepared tubes of radium salts age for a few weeks before using them. Looking back to Soddy's decay chain, hard betas and gammas are not produced until we reach radium C_1 and radium C_2. A fresh preparation of radium salts would only be emitting alpha radiation, but after around three weeks, the radium and radium emanation (the gas that is the next step in the decay chain) will reach radioactive equilibrium. At that point, the amount of radium emanation decaying into radium A is exactly balanced by the amount of radium emanation being produced by radium, and the radioactivity is at its maximum level.[199] The radium C_1 and radium C_2 themselves have short half-lives, but since they are continually being created by radioactive decay, an aged tube of radium salts is an emitter of all three kinds of radioactivity. If a physician bought radium salts already encapsulated in a small tube, the preparation would likely have

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[198] This is, for example, the view presented in Heber Robarts, *Practical Radium: The Causation of Cancer, and its Curability with Radium* (St. Louis: Nixon-Jones Printing, 1909).

[199] For an explanation of this see, for example, the explanation in Frederick Soddy, "Radium: A Method of Applying the Rays from Radium and Thorium to the Treatment of Consumption," *British Medical Journal* 2 No. 2221 (July 25, 1903): 197–199. This explanation is based on the discovery Soddy made with Ernest Rutherford of the transmutation theory of radioactivity—the idea that radioactive elements change into different elements in the process of giving off radioactivity, the understanding behind radioactive decay chains. Ernest Rutherford and Frederick Soddy, "The Radioactivity of Thorium Compounds, I and II," *Transactions of the Chemical Society of London* 81 (1901): 321–350, 837–860.

already aged to equilibrium due to the shipping time from Europe; but if he was having his radium salts sealed up in a glass tube more suitable for his therapeutic needs, he needed to be aware of the time needed to reach equilibrium or risk uneven treatments with the newly-prepared sample.

So what did physicians consider important for them to understand about the physics of radium? In this first decade, the degree of physics knowledge possessed by radium therapists varied greatly from physician to physician. An individual radium therapist's background, training, and interest in physics and physics-based therapies determined how important he felt physics knowledge was to his use of radium. Those physicians who were more strongly connected with physics began to establish the consensus that would become clear in 1910's that an understanding of the physics of radium was critical to safe and effective radium therapy.

In the twenty-six articles on radium that appeared in the *Journal of the American Medical Association* (*JAMA*) through 1910 (the first appeared in 1902), eight articles—31%—were about radium and the physics of radium. Six articles focused on radium therapy generally, and six focused on radium in the treatment of cancer. The few remaining articles were on radium in surgery, the dangers of radium, and the physiological effects of radium. The fact that the majority of those radium therapy articles focus on the physics of radium is partly indicative of the paucity of solid medical facts on radium compared to scientific facts. However, those scientific facts would not have been of interest to *JAMA* editors and readers if they were not thought to be important for therapy.

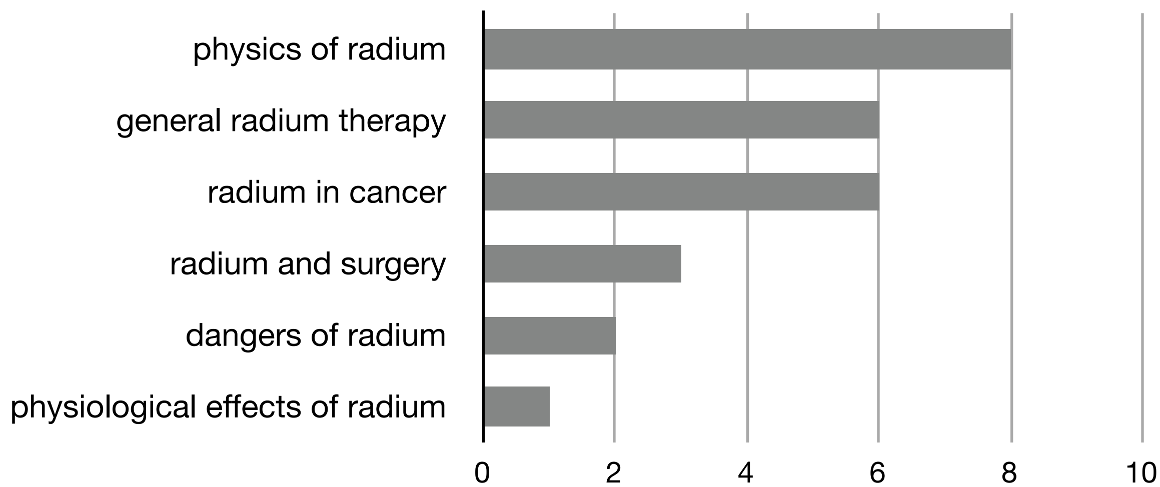

Figure 2.4. *JAMA* articles on radium, 1900–1910.

The first article that appeared in *JAMA* on radium, in 1902, was introductory and optimistic. "It would appear we have in [radium] a therapeutic agent of considerable promise," the author reported, especially in the treatment of cancer.[200] The next year, two editorials appeared that focused almost exclusively on the scientific properties of radium.[201] Notable among the articles that focused on the therapeutic uses of radium were Morton's article on sunshine therapy and physician Max Einhorn's article that introduced a new apparatus that could introduce radium into the esophagus to treat esophagal cancers.[202] Robert Abbe published twice, advising radium therapists to use

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200 "The Radium Rays in Therapeutics," *JAMA* 39 (1902): 846.

201 "A Radium Calculation," *JAMA* 41 (1903): 376–377. "Remarkable Properties of Radium," *JAMA* 40 (1903): 1293–1294.

202 William James Morton, "Fluorescence Artificially Produced in the Human Organism: By the X-Ray, By Radium, and By Electric Discharges, As a Therapeutic Method," *JAMA* 44 (1905): 1009–1016. Einhorn, "Radium Treatment of Cancer of the Esophagus."

strong radium samples in repeated short sessions.[203] He based his 1910 report on experience drawn from over 500 radium therapy cases. In 1904, physician William Allen Pusey, who worked with X-rays and radium, summarized the current best understanding of the physics of radium and presented a literature review of clinical results with radium in a paper given to a meeting of the AMA.[204] In his opinion, which was supported in the discussion of his paper by other physicians who had worked with X-rays or radium, radium was indicated for use in cases where X-rays were indicated, and while radium might be able to help in certain kinds of cases, "it is highly improbable that the use of radium is going to be of epoch-making importance in therapeutics" or that radium would replace X-ray or ultraviolet light therapy.[205]

The most scientifically technical of the *JAMA* articles of this period was based on a letter to *Nature* by Ernest Rutherford, on radium and radium emanation. In the 1909 *JAMA* article, Philadelphia physician John Shober took Rutherford's 1906 observation that charcoal easily absorbs radioactivity when put in contact with radium emanation as a starting point and, with the help of University of Pennsylvania physicist Arthur Goodspeed, adapted Rutherford's setup and proposed a way that radioactive charcoal can

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[203] Robert Abbe, "Radium in Surgery," *JAMA* 47 (1906): 183–185. Abbe, "Radium's Contributions to Surgery."

[204] William Allen Pusey, "Radium and Its Therapeutic Possibilities," *JAMA* 43 (1904): 173–180.

[205] Ibid., 179.

be used therapeutically.[206] Most of the physics-focused *JAMA* articles were more general than this, without the immediate application to therapy. Shober's article is also another example of the collaborations that existed between radium therapists and physicists in this experimental period. Shober was inspired by the research of one of the world's leading radioactivity researchers, and went to a local university physicist for scientific and technical assistance in bringing the physics discovery into his clinic.

Radium therapy was founded on physics, and as we have seen, this foundation was considered very important by radium therapists. The physics of radioactivity and radioactive decay chains shaped how physicians understood and applied their therapies. Connections with radioactive networks provided early adopters of radium therapy with radium, prestige, and scientific knowledge. There were no standards of dosage in this experimental period, and methodology varied from case to case and physician to physician. What American radium therapists held in common, though, was an interest in physical therapies and the foundational importance of the new science of radioactivity to their therapy.

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[206] John B. Shober, "Emanation of Radium Absorbed and Retained by Cocoanut Charcoal: An Advance in Radium Therapy," *JAMA* 53 (1909): 624–8. Goodspeed worked with both radium and X-rays, and was involved with radiation therapy. Goodspeed is also sometimes credited, with W. N. Jennings, with producing the first X-ray exposure in 1890, six yeas before Roentgen announced the new rays to the world. See, for example, "Early Years" in *Radiology at the University of Pennsylvania, 1890–1975* (Philadelphia: University of Pennsylvania Press, 1981), accessed on the University of Pennsylvania *Scholarly*Commons Repository: http://repository.upenn.edu/penn_history/7/.

Chapter Three

Teaching and Learning Radium Therapy, 1900–1932

Introduction

Radium therapy texts, written for a medical audience, provide a unique meeting place for physics and medicine. From them we can see the specific ways physical knowledge shaped radium therapy and how the influence of physics changed over the experimental and professionalizing periods of American radium therapy. An analysis of radium therapy courses also illuminates the changing influence of physics. In the first period, physics was understood to be clinically relevant but was not consistently related to clinical concerns. In the second period, not only was physics knowledge directly related to therapeutic practice, but scientific expertise was strongly argued for as a requisite for radium therapists.

A New Physical Therapy: Early Texts Discussing Radium Therapy

The radium craze of the first decade of the twentieth century encouraged some physicians to investigate radium therapy, and there were a handful of texts available to them to supplement the sparse American medical literature. In these texts, it was standard to find a basic introduction to the physics of radium and radioactivity. Readers learned that radioactivity was comprised of three different rays, and that these rays had different effects on the body. The relevance of adapting physics measurements for clinical use, however, was not appreciated in this experimental period.

The books analyzed in this subsection are Charles Allen's *Radiotherapy and Phototherapy* (1904), Samuel Tracy's chapter in Solomon Cohen's *A System of Physiologic Therapeutics* (1905), William King's *Static, High Frequency Radio, Photo and Radium Therapy* (1905), Mihran Kassabian's *Röntgen Rays and Electro-Therapeutics*, Sinclair Tousey's *Medical Electricity and Röntgen Rays* (1910) and Charles Baskerville's *Radium and Radio-Active Substances* (1905).[207] The first five of these were books written by physicians, and focused on physical therapies—therapies like electrotherapy and X-ray therapy, which were based on discoveries in physics.[208] For these five authors, their interest in physical therapies led to their interest in radium therapy and their inclusion of a chapter on this new therapy in their texts. Baskerville was a chemist and active radioactivity researcher at the College of the City of New York, and, unlike the other five books we are considering in this section, *Radium and Radio-*

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[207] Charles Warrenne Allen, *Radiotherapy and Phototherapy, Including Radium and High Frequency Currents, Their Medical and Surgical Applications in Diagnosis and Treatment* (New York: Lea Brothers & Co., 1904). Solomon Solis Cohen, ed., *A System of Physiologic Therapeutics: A Practical Exposition of the Methods, Other than Drug-Giving, Useful for the Prevention of Disease and in the Treatment of the Sick*, Volume 11 (Philadelphia: P. Blakiston's Son & Co., 1905). William Harvey King, *Static, High Frequency Radio, Photo and Radium Therapy* (New York: Boericke & Runyon, 1905). Mihran Krikor Kassabian, *Röntgen Rays and Electro-Therapeutics, with Chapters on Radium and Phototherapy* (Philadelphia: J. B. Lippincott, 1907). Sinclair Tousey, *Medical Electricity and Röntgen Rays, With Chapters on Phototherapy and Radium* (Philadelphia: W. B. Saunders, 1910). Charles Baskerville, *Radium and Radio-Active Substances: Their Application Especially to Medicine* (Philadelphia: Williams, Brown, & Earle, 1905).

[208] All held M.D.s; Kassabian directed the Philadelphia Hospital's Röntgen Ray Laboratory, Allen was a professor of dermatology at the New York Post-Graduate Medical School, and King was an electrotherapist at the homeopathic Flower Hospital in New York City.

Active Substances focused exclusively on radium and radium therapy.[209] Baskerville originally envisioned his book as being more technical; however, Ernest Rutherford and Frederick Soddy both published books on radioactivity in 1904, so Baskerville left out many "technical details" and emphasized medical applications of radium.[210] Baskerville, like the five physician authors, considered the influence of physics on radium therapy to extend past the discovery of radium into clinical practice.[211]

A discussion of the basics of the physics of radium and radioactivity was a core component of these six texts' presentation of radium therapy. Although details of the nature of radioactivity were not agreed upon across these texts, they all made it clear that radium emitted three different kinds of rays, and that their differences had clinical implications. Readers of these texts learned that radioactivity was comprised of alpha, beta, and gamma rays; and in these texts these rays were differentiated either on the basis

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[209] Baskerville had previously announced his discovery of two new elements which he separated from thorium: carolinium and berzelium. See Charles Baskerville, "On the Existence of a New Element Associated with Thorium," *Journal of the American Chemical Society* 23 (1901): 761–774 and Charles Baskerville, "Thorium; Carolinium, Berzelium," *Journal of the American Chemical Association* 26 No. 8 (1904): 922–942. His discoveries were taken quite seriously, but eventually the elements were found to be spurious. One refutation of Baskerville's discoveries can be found in R. J. Meyer and A. Gumperz, "Zur Frage der Einheitlichkeit des Thoriums," *Berichte der Deutschen Chemischen Gesselschaft* 38 (1905): 817–825.

[210] Baskerville, *Radium and Radio-Active Substances*, preface. Ernest Rutherford, *Radio-Activity* (Cambridge: Cambridge University Press, 1904). Frederick Soddy, *Radio-activity: An Elementary Treatise, from the Standpoint of Disintegration Theory* (New York: D. Van Nostrand, 1904).

[211] In addition to Baskerville's text, there was one other American text devoted entirely to radium therapy in this early period: Heber Robarts' *Practical Radium: The Causation of Cancer, and its Curability with Radium* (St. Louis: Nixon-Jones Printing Co., 1909), which, because of its idiosyncracy, is not a useful source for drawing conclusions about the interactions between physics and medicine. It was part guide to treating cancer and part advertising pamphlet: Robarts was both a physician and a supplier of medical radium. His self-promotion is mainly concentrated in the final three chapters, but contributed to the overall exultant tone of the text. One chapter was an extensive invented dialogue between Doctor Interrogator and Doctor Radium, an obvious stand-in for Robarts ("Dr. R" even refers to himself as "Robarts" at one point in the dialogue), wherein Dr. Radium/Robarts instructs the simple Dr. I in the treatment of a patient with radium.

of their penetrative ability, their particulate nature, or on their electric charge. For his part, Tousey argued that "the *alpha* and *beta* rays are those that are chiefly effective for therapy."[212] Physicists had discovered that alphas and betas were more easily absorbed than gammas, so for a physician wanting to use these weaker rays in therapy, "the radium should be directly in contact with the surface or only separated from it by the thinnest practicable covering," so that they would be absorbed by the patient's skin and not an interposing material.[213]

Kassabian, on the other hand, considered betas to be "probably instrumental in causing the burns that have been recorded," because of their moderate penetrative ability and the comparatively large numbers of betas produced by radium salts.[214] The implication of this reasoning was to limit patients' exposure to betas—either through filtration or by limiting exposure time—if a physician wanted to decrease the risk of burns. Similarly, in his book Baskerville passed on the advice of pioneering radium therapist Francis Williams that "under no circumstances should the *β*- and *γ*-rays be used together for deep-seated diseases, because the *β*-rays would cause serious injury before the *γ*-rays had time to produce a beneficial effect."[215] Similarly, Allen told his readers: "*Caution*. The authors warn against the use of plaques having too great radioactivity, as they are liable to produce more harm than good." Plaques were flat and could be placed directly against the skin, and were used to treat superficial conditions. Allen's (implicit)

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212 Tousey, *Medical Electricity and Röntgen Rays*, 1042.

213 Ibid.

214 Kassabian, *Röntgen Rays and Electro-Therapeutics*, 503.

215 Baskerville, *Radium and Radio-Active Substances*, 133–134.

reasoning was that strong plaques would produce more gammas, which, because of their greater penetrative power, would damage underlying tissues while doing nothing to treat the skin.[216] Radium therapists in this experimental period were well aware of radium's ability to burn the skin, and of the dangerous symptoms that accompanied the similar burns produced by X-rays. Protection against burns was discussed, but not emphasized, in these texts.[217] However radium burns, while painful, did not appear to lead to the long-term effects—progressive burns and ulcers which could necessitate amputation and might lead to death—which could accompany X-ray burns. In summary, although the specific distinctions between alphas, betas, and gammas were not consistent across these texts, it was clear that alphas were the weakest and gammas the strongest: and that physicians should, therefore, be mindful of the kind of rays they used in therapy.

Being aware of the different kinds of rays, and their different strengths, was important for early radium therapists for another reason in addition to minimizing burns. Animal and plant experiments had shown a general trend that exposure to weak amounts of radioactivity encouraged growth while exposure to strong sources damaged cells. Physicians had to decide if they wanted to promote cell activity or provoke a destructive effect, and what seemed to make the difference was the strength of the radium sats or the

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[216] Allen, *Radiotherapy and Phototherapy*, 534. (Allen is the only author but on the flyleaf it is stated that the book appeared "With the Co-Operation of Milton Franklin, M.D., Lecturer on Electro-Radiotherapy, New York Polyclinic Medical School, and Samuel Stern, Radiotherapist to Dr. Lustgarten's Clinic at the Mount Sinai Hospital; Clinical Assistant to the Skin Department of the New York Post-Graduate Medical School.")

[217] Allen, who consulted with William Hammer, is the only one of these five authors to explicitly advise radium therapists to take precautions with their own exposure to radioactivity, citing Hammer's temporary blindness which arose after he placed his head in a box with walls coated with radium's active deposit. "The operator" of radium should therefore "protect himself from long exposures" to radioactivity. Ibid., 527.

rays being selected. Tousey explained to his readers how this could be used to tailor radium therapy to specific cases:

> 1. The mildest applications modify the nutrition of the tissues and stimulate the growth of hair and the activity of the glandular elements. They may be useful in cases of atrophy, atony, or ulcers of the skin, and in ophthalmologic and gynecologic cases. 2. A more or less destructive effect may be produced upon such affections as epithelioma, lupus, nevus (birth-mark), verruca (wart), keloid, and a variety of other localized conditions.[218]

In other words, certain conditions might be helped by weak radiation encouraging cell growth, while other conditions might be helped be strong radiation slowing cell growth or destroying cells entirely. Selecting the appropriate therapy required a careful choice of the radioactive source and rays to be used.

Baskerville's explanation of the distinctions between alpha, beta, and gamma rays is the clearest in medical texts in this period. Alphas are identified with canal rays, betas with cathode rays, and gammas are presented as "very similar to the Röntgen rays."[219] Baskerville also gave the ratio between the rays' ionization abilities: 10,000 : 100 : 1 for alphas : betas : gammas.[220] There seemed to be a correlation between ionization and therapeutic effect, with higher ionization relating to more changes in the tissue, so this ratio was important for therapists in selecting rays for therapy.

Baskerville also discussed radium's decay chain, an important consideration for therapists as their radium salts contained not only radium but also its daughter products. The solid substances produced along radium's decay chain were called the active deposit,

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[218] Tousey, *Medical Electricity and Röntgen Rays*, 1055.

[219] Baskerville, *Radium and Radio-Active Substances*, 36–37.

[220] Ibid., 37.

or were referred to as "induced radioactivity," since the deposition of these elements onto a surface would seem to render it radioactive. Ernest Rutherford and Howard Turner Barnes studied how the products in the active deposit, along with radium and radium emanation, all individually contributed to the overall radioactivity and heat production of a preparation of radium salts. Baskerville summarized their results in a table, the data from which are reproduced in Table 3.1.

Active Products	Nature of rays	Percentage proportion of total activity measured by rays	Percentage proportion of total heating effect
Radium freed from active products	alpha rays	25	25
Emanation	alpha rays	18	
Emanation X (1st change)	alpha rays	15	41 [Em & Em X]
" (2d change)	No alpha rays	0	
" (3d change)	alpha, beta & gamma rays	42	34 [2nd & 3rd changes]

Table 3.1. Contributions of the constituent parts of a preparation of radium salts to the salts' heat and radioactivity, taken from a chart based on the research of Rutherford and Barnes from Baskerville, Radium and Radio-Active Substances*, 89.*

On the basis of his further research, Rutherford was able to refine the understanding of the decay chain of radium, which Baskerville presented as well:

Radium → Rad. Em → Rad. A → Rad. B → Rad. C → Rad. D → Rad. E [221]
\ \ \ / | \ \ \
α *α* *α* *α β γ* *β* *α*

[221] Ibid., 114.

Radium A, B, and C were identified as the active deposit of rapid change (i.e. with a short lifetime) and radium D and E as the active deposit of slow change (i.e. with a long lifetime). What this information made apparent to physicians was not only that their radium salts contained several radioactive elements, but also that radium and its gaseous daughter product radium emanation did not produce betas or gammas. These rays were only produced by elements in the active deposit. After their production, therefore, radium salts needed to age before betas and gammas were produced.

It also followed that the active deposit could be collected and itself used therapeutically. Only Tracy discussed this option in a substantive way. He found it very useful therapeutically that the active deposit can be put into a physiologic salt solution, which could then be used "in lotions and compresses, for dressing, gargled, collyria [eyewash], sprays, nasal and other douches, hypodermatic injections, hypodermatoclysis [hypodermatic injection in large volume], and even intravenously."[222] Tracy mentioned William Morton's liquid sunshine therapy based on the use of quinine, which is fluorescent, in combination with X-rays and/or radium.[223] Baskerville also discussed William Morton's fluorescent therapy, but included Cleveland physician Myron Metzenbaum's proof that Morton could not be making patients' innards glow.[224] That the other authors did not discuss the internal use of the active deposit, or of radium salts,

[222] Cohen, ed., *A System of Physiologic Therapeutics*, 147.

[223] Tracy also cited an 1867 study suggesting that there was a substance resembling quinine produced in the body, and that quinine was curative because it corrected an imbalance in the body's natural internal fluorescence. Ibid., 150.

[224] Baskerville, *Radium and Radio-Active Substances*, 140.

demonstrates that it was not a mainstream technique within this new experimental therapy.

Dosage was not standardized in this experimental period, and there was little discussion of the importance of accurate measurement to determine dosage. A discussion of the physiological effects of radium was standard in these books, sometimes with a formal literature review. Specific attention was given to its effects on the skin, the eyes, and in the diminution of pain. Most of the authors also discussed radium's apparent bactericidal effects. What was most emphasized was radium's use in the treatment of cancers. Although there was significant overlap in what conditions the authors found radium especially useful in treating, there were no standard methodologies or dosages associated with these conditions. What's more, how these methods or dosages might be scientifically verified was generally ignored.

The physical equipment associated with understanding and measuring radioactivity is generally ignored in these texts. This meant that readers of most of these texts would not understand how they might confirm the strength of their radium salts, or the importance of doing so. King gives a detailed description and a schematic of a spinthariscope, which was developed by William Crookes as a demonstration of radioactivity but had little utility outside of its pedagogical interest and novelty. The spinthariscope was a small tube with a zinc sulfide screen at one end, a tiny amount of radium salt affixed to a needle a small distance from the screen, and a lens for viewing at the other end of the tube; when one looked through a spinthariscope one could see the scintillations in the zinc sulfide caused by the radioactivity, each spark corresponding to an alpha particle.[225] Laboratory physics equipment, like electroscopes and photographic plates, could be useful to a radium therapist to measure the activity of his sources or as a check of therapeutic efficacy. Baskerville notes that Tracy used photographic plates to verify that the breath was radioactive after inhaling thorium emanation.[226] But the overall scant attention given to this equipment and its uses in these texts demonstrates the general lack of appreciation of its great utility in this early period.

Only Tracy discussed the ways of measuring radioactivity and the equipment involved. He explained to his readers that radioactivity can be tested by electroscope, photographic plate, or by an electric method involving ionization. He cites Columbia physicist George Pegram in claiming that the electric method is the most accurate, and details how in this method a quadrant electroscope can be used to precisely measure the ionization of the air, caused by radioactivity, between two conducting plates.[227] This was the most precise method available but involved scientific equipment only physicists or chemists would possess. If a physician wanted to measure the activity of his radium salts via the electric method, he would have to reach out to a scientist who could make those measurements in his laboratory.

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[225] Baskerville evocatively describes a spinthariscope as analogous to a thunder storm, in which: “small aqueous vesicles forming the clouds, each vesicle charged with a small amount of electricity, unit with with one another forming larger vesicles. As they are spherical the larger vesicles show a smaller surface in proportion to the mass; consequently the electrical tension upon the surfaces becomes greater as the vesicles grow into drops of water and it is the uniting into one great electrical spark of an infinite number of small electrical sparks passing from drop to drop that produces the lightning flash of thunder. Radium, acting upon the atmosphere in contact with it, or in its immediate vicinity, discharges the electricity from certain molecules to certain other molecules, producing miniature reactions. ... Were our ears acute enough it might be possible to distinguish these infinitely small claps of thunder.” Ibid., 97–98.

[226] Ibid., 138–139.

[227] Cohen, ed., *A System of Physiologic Therapeutics*, 134–135.

This could present a barrier to a radium therapist, who might therefore decide that he preferred to measure the radioactivity of his salts with photographic plates. By letting the radioactivity expose the plate for a given period of time and then comparing that plate with a plate that had been exposed by salts of a known strength for the same length of time, the physician had a qualitative measure of his salts' activity. This provided useful information, but was not as precise as the electrical method.

Baskerville showed his lack of clinical experience when he stated that "it is assumed, of course, that any physician inaugurating experiments on human subjects will have determined the strength of the preparation before applying it."[228] He clearly believed this measurement to be important for physicians but did not provide basic instructions for how a physician might verify the strength of his radium salts, nor did he explicitly suggest that physicians contact a physicist or chemist to do this measurement for them. Although verification of radium salts was standard practice in scientific laboratories like those Baskerville was familiar with, the other texts demonstrate that it was not standard practice in clinics. The fact that only one of the six texts we are considering here discussed the measurement of radioactivity is a strong indication that during this experimental period most radium therapists were content to trust that the strength they paid for was the strength they received. It was well understood that the activity of the salts being used in therapy was one of the critical components of determining dosage, even in this period where dosage was far from standardized, so this was a great deal of trust for physicians to place in radium manufacturers and sellers. In

[228] Baskerville, *Radium and Radio-Active Substances*, 133.

later years, as collaboration with physicists became more common for radium therapists, it was found that in many cases this trust was seriously misplaced, with many physicians using radium salts much weaker than they expected.

In this first period of American radium therapy, the main impact of physics was the identification of alpha, beta, and gamma rays. Although they were not consistently defined in the texts of this period, it was generally understood that alphas were the weakest and gammas the strongest, and that the rays therefore had different effects on the body. These authors encouraged physicians to be mindful of what rays were being delivered to patients. Physicists were also aware of the importance of accurate measurement of radioactive sources, but the relevance of these methods to physicians was generally not recognized in this period. Some physics knowledge informed radium therapy, but the practices of physics laboratories had little relevance.

Texts in the Second Period of American Radium Therapy: Demonstrating Standards

In the second period of American radium therapy, from 1910 to around 1932, texts written by physicians devoted entirely to radium therapy became available. These texts were different in several ways from those of the earlier experimental period, besides their exclusive focus on radium. The authors were more scientifically informed, and found greater relevance of physics to radium therapy. They argued convincingly for the necessity of scientific expertise in radium therapy. Physics knowledge was directly connected to the clinical considerations of their readers. The measurement of radium samples was emphasized, and physicians were encouraged to form new collaborations with professional physicists.

In this section we will focus on four important American texts which concentrated on radiotherapy. All of these were written by physicians: William S. Newcomet's *Radium and Radiotherapy* (1914), George Miller MacKee's *X-Rays and Radium in the Treatment of Diseases of the Skin* (1921), Frank Edward Simpson's *Radium Therapy* (1922), and Daniel Thomas Quigley's *The Conquest of Cancer by Radium and Other Methods* (1929).[229] Newcomet was a radiologist, MacKee and Simpson were dermatologists, and Quigley was a surgeon.[230] Of the two dermatologists, MacKee was much more experienced with X-rays than with radium; whereas Simpson was the director of an eponymous radium institute in Chicago. All these authors had personal experience with radium therapy and spoke from a first-hand, clinical perspective.

These texts, unlike earlier ones, made claims for the necessity of expertise—clinical and scientific—in radium therapy. MacKee perhaps stated it most strongly: at the

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[229] William S. Newcomet, *Radium and Radiotherapy: Radium, Thorium, and Other Radio-Active Elements in Medicine and Surgery* (Philadelphia: Lea & Febiger, 1914). George Miller MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin* (Philadelphia: Lea & Febiger, 1921). Frank Edward Simpson, *Radium Therapy* (St. Louis: C. V. Mosby Company, 1922). Daniel Thomas Quigley, *The Conquest of Cancer by Radium and Other Methods* (Philadelphia: F. A. Davis, 1929).

[230] Quigley was remarkably enthusiastic about the achievements of radium in the treatment of cancer. Unlike most of his colleagues, he felt confident enough to declare that in radium "*we now have a cure for local cancer, a thing which we have never had before*." Quigley, *The Conquest of Cancer by Radium and Other Methods*, 454. Emphasis in the original. This came with the caveat that cases of advanced cancer remained beyond the hope of therapy; but early cases could be treated with radium and slightly more advanced cases with a combination of surgery and radium, and even hopelessly advanced cases could find a cessation of pain from the application of radium. Ibid., 455. Striking a not-uncommon moralistic tone, Quigley declared that the advanced case "has arrived at its unhappy condition because of many, many times disregarding the red lanterns that Nature has hung along the road. ... [This case] is hopeless, deserves to be hopeless, and perhaps always will be hopeless." Ibid.

very beginning of his text, he told his readers that "every physician who employs *x*-rays and radium should possess modern knowledge and equipment."[231] He also expected that "many readers of this book will wonder why so much space is devoted to details which apparently concern only the pure radiologist" and bluntly told his readers that "no physician should employ either one of these agents [X-rays or radium] unless he has a thorough and very general knowledge of their physics, therapeutics, biology, etc."[232] To attempt radium therapy without understanding this would be risking ineffective or injurious treatment. Quigley likened a physician, untrained in the science of radioactivity or in radium therapy, acquiring a tube of radium and expecting cures to a person thinking "that if he were to possess himself of a scalpel and a few forceps and other surgical instruments, he would be in a position to obtain the brilliant surgical results obtained by the trained and educated surgeon."[233] Newcomet explicitly identified one of the weaknesses of radium therapy in its early period—the lack of verification of radium salts' strength—and on that basis "warned" his readers "to familiarize themselves to some extent with the physics involved, or have some physicist of standard reputation assist them in their work."[234] The argument for the necessity of scientific expertise was hardly present in the books of the earlier period, where radium therapy was presented as just one component of the armamentarium of physical therapies.

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231 MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, v.

232 He further explained that though most readers were only interested in "lighter and superficial work," they must understand the physics and physiology of deep therapy. Ibid., 176–177.

233 Quigley, *The Conquest of Cancer by Radium and Other Means*, 216.

234 Newcomet, *Radium and Radiotherapy*, vi. He argued that many physicians had abandoned radium therapy because of poor results—results obtained because their radium was much weaker than what they had paid for and had never had its strength verified.

Although the need for expertise was agreed upon across these four books, MacKee and Quigley disagreed on whether future radium therapists would be dedicated, expert specialists. Quigley, himself a surgeon, believed that radium found its greatest utility through surgical implantation and argued that radium therapists ought to be specialized surgeons. "Radium in the hands of general practitioners, various 'specialists,' X-ray and similar non-surgical operators," he argued, "can never be anything but a commonplace instrument, incapable of brilliant results, and with great possibilities for producing harm."[235] He hoped that "in the future, the surgeon who uses radium will preferably limit his practice to radiological work and radiological surgery," in essence making radium therapy a surgical sub-discipline.[236] MacKee, on the other hand, stated that

> radium therapy, like roentgen therapy is not and will never by entirely limited to pure specialists. Specialists in various branches of medical practice and many general practitioners of medicine, especially those in small centers, will find use for these agents.[237]

Even in this view, however, it was critical for the radium therapist to have expert clinical and scientific knowledge. And whatever their belief on the future of radium therapy, all of these authors stressed the importance of this expert knowledge.

These four books discussed the physics of radium and radioactivity, which the earlier texts did as well, but in these newer books the authors directly connected this science with clinical considerations. Newcomet's text, especially, is very detailed: he

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[235] Quigley, *The Conquest of Cancer by Radium and Other Means*, 216.

[236] Ibid., 523–524.

[237] MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, 176.

presented the decay chains of uranium, actinium, and thorium, with sections on each of those parent elements, and a section on radium (which is part of the uranium decay chain).[238] He explained the distinction between the active deposit of rapid change and the active deposit of slow change: the active deposit of rapid change included Radium A, B, and C, which all has half-lives in minutes, while the active deposit of slow change included Radium D and its daughter products, as Radium D has a half-life of around 20 years. Adding specificity to the understanding of the earlier period, Newcomet pointed out that betas and gammas are produced by the active deposit of rapid change. In his 1905 book, Baskerville had explained that the active deposit was the source of radium salts' beta and gamma emissions, but drew no clinical conclusions from this. A reader of his book may have concluded on his own that newly-produced radium salts needed to age before they began to produce betas and gammas. Newcomet explicitly pointed this out,

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238 Newcomet's text was not without errors, however. He explained the equation governing radioactive decay, and although he understood the consequences of this equation (for example, the necessity of aging radium tubes), he erred in explaining its specifics. He presented the equation in the form: $\frac{I_t}{I_0} = \varepsilon^{-\lambda_t}$, and explained that λ was the radioactive constant and that I_o was the initial activity and I_t was the activity at time time. However, the correct expression for their ratio is $\frac{I_t}{I_0} = e^{-\lambda t}$, with the constant *e* not the variable *ε*, and with the time *t* multiplied by *λ* rather than as a subscript. The radioactive constant, *λ,* should be multiplied by the time elapsed, *t*; it was most likely a typographical mistake that *t* appeared as a subscript in Newcomet's equation. However, Newcomet's equation replaced the mathematical constant *e* with the variable *ε*. He also explained that *ε* is "the number 2,71828 in the case of polonium," clearly misunderstanding the importance of *e* (which is a fundamental constant in mathematics approximately equal to 2.71828) and the fact that *λ* is specific to the radioactive element in question. (*e* is the base of the natural logarithm, and is defined as $\lim(n \to \infty) \left(1+\frac{1}{n}\right)^n$. *ε* has no defined meaning in mathematics, apart from its customary use to represent a small increment when studying variations, and can be used to represent any variable.) Despite this bizarre error, Newcomet's science is generally reliable. Newcomet, *Radium and Radiotherapy*, 60–61.

and further stated that a period of one month's aging was necessary before radium salts would reach radioactive equilibrium and were suitable for therapeutic use.[239]

The physics of radioactivity also led to a better understanding of the specifics of filtration of therapeutic sources. As in the first period, readers of these books learned that radioactivity was composed of alpha, beta, and gamma rays; but in these books in the second-period, the rays' differences in penetration, ionization, and composition were uniformly agreed upon. In addition, betas seemed to have a fairly wide range of penetrability, and could be produced as a secondary radiation by gammas striking matter. Newcomet explained that the ratio of the penetrability of the alpha, beta, and gamma rays was roughly 1:100:1000, and illustrated this with the chart in Fig. 3.1.

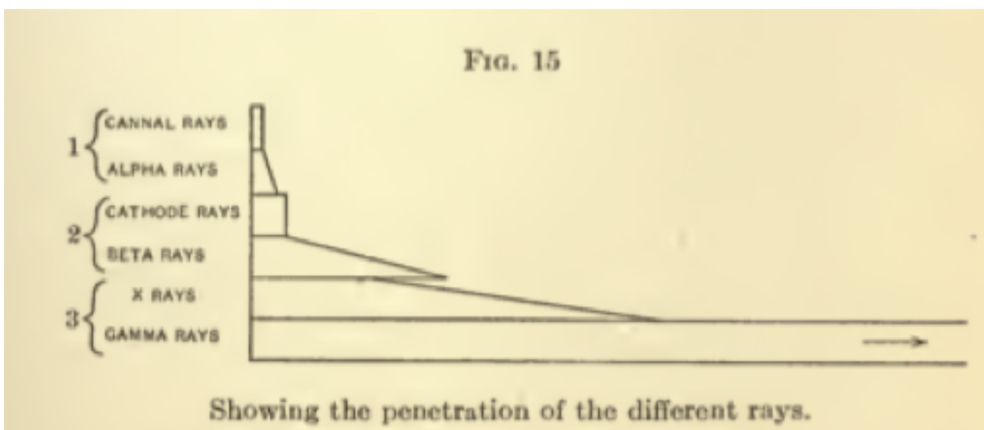

Figure 3.1. Newcomet, Radium and Radiotherapy*: 59.*

[239] Newcomet, *Radium and Radiotherapy*, 36.

Newcomet also provided a chart (shown in Fig. 3.2) detailing how the rays could be

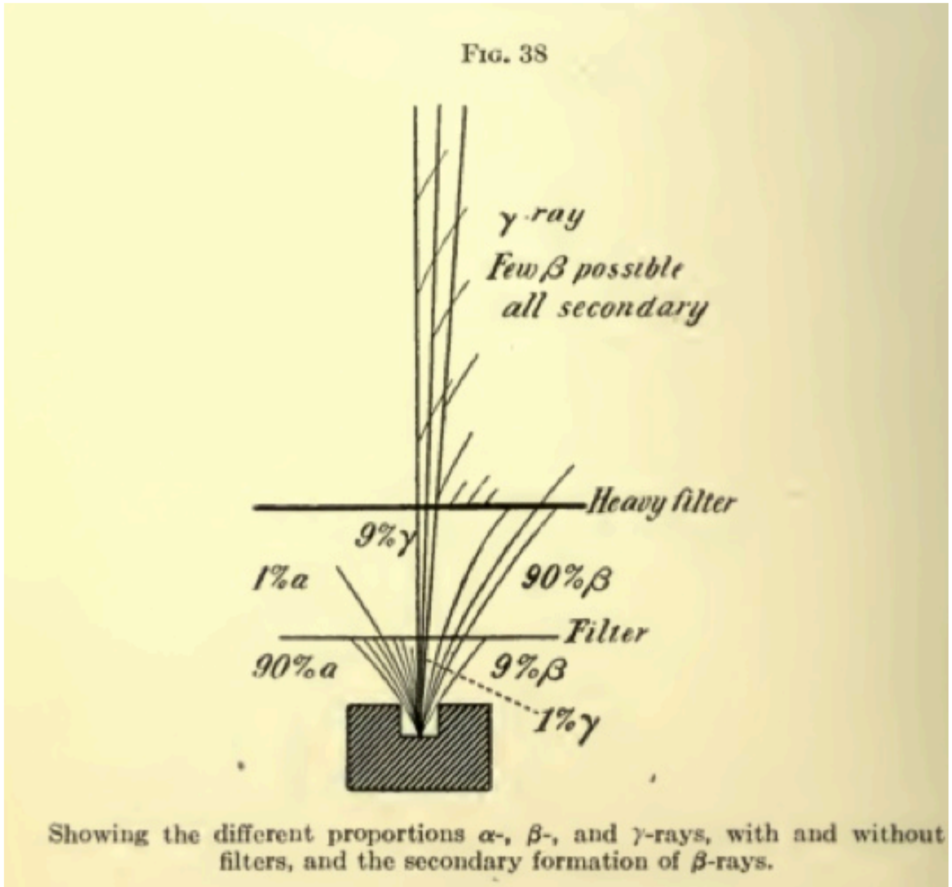

Figure 3.2. Effects of filtration on the rays from radium. Newcomet, Radium and Radiotherapy*: 130.*

filtered, and what percentage of each kind would be present after filtration.

Physicians' improved understanding of the physics of radioactivity made clear the necessity of filtering out secondary radiation when gamma rays are desired for therapy, as was becoming the consensus. Clinical results were leading to the conclusion that hard betas and gammas were best for therapy generally, and exclusively gammas if a deep-seated tumor was being treated. A fairly heavy filter was therefore needed between the source and the patient's skin, and all four of these texts presented calculations or tables detailing what materials, and in what thicknesses, filtered out specific percentages of rays as was preferred for various conditions. One of the reasons for filtration was the prevention of burns. In this second period, patients' potential averse reactions to radium were understood to include not only burns but also "nausea, vertigo lasting often for several days, after a marked degree of irritability and sleeplessness, ... marked gastro-intestinal disturbance, pain, diarrhea, vomiting and at times the cardiac symptoms may be most alarming."[240] These symptoms spoke loudly of the need for careful filtration—but filtration alone was not enough, as MacKee noted that patients had died from overexposure to even "heavily filtered" radiation.[241]

Physics knowledge of the filtration of different rays also influenced the physician's choice of radium applicator. The most common were needles, tubular applicators, flat varnish applicators, and soft toile applicators, and MacKee compared these applicators and their different inherent filtrations. Radium needles contained a small amount of radium salts, and were silver or platinum, to absorb weaker rays. Glass tubes of radium salts were generally kept within two layers of shielding, the inner to absorb alphas and weak betas, and the outer to absorb secondary betas.[242] Tubes and needles were commonly used and MacKee had little to say in the way of negatives for

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[240] Ibid., 158.

[241] MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, 228.

[242] Newcomet warned his readers of the potential danger of sealed glass tubes: "as they age, gases are given off and *explosions have resulted*; therefore in handling old sealed tubes, the greatest care must be taken to guard against this accident." *Radium and Radiotherapy*, 126. These explosions were rare but did occur.

them.[243] The varnish of the flat applicators blocked out alphas and soft betas; but they were fragile even when new, and after a few years the varnish became so brittle that it would break off and consequently radium could be lost. Manufacturers, MacKee complained, often provided an attractive wooden case lined with velvet and covered with leather rather than a protective lead case.[244] Toile applicators, made of cloth coated with a radium varnish, were "not popular" because they were easily lost and do not filter alphas. The radium applicators available had different inherent filtrations, and the rays desired for therapy influenced the physician's choice of applicator.

A major difference between the second period of American radium therapy and the first was a growing awareness of the importance of standardized and reliable measurement, which is demonstrated by the texts of the second period. A crucial catalyst for this change was the establishment of the curie by the scientific community. The new unit was set as a standard measure of radioactivity, and the activity of radium salts could be expressed in curies by comparing its gamma emission to that of a known standard. As Newcomet told his readers, "Until the International Committee established the Curie [sic] unit for the measurement of radio-activity there were numerous methods and standards employed, all more or less confused, depending upon ideas developed in different countries by societies and individuals."[245] Prior to the establishment of the curie, medical articles on radium therapy used a variety of units for measuring radioactivity, so the

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[243] Radium tubes were particularly well suited to treat curved areas, and a mold made from dental molding compound was commonly used in concave surfaces to to keep the tubes in the desired positions. Ibid., 200.

[244] MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, 189–190.

[245] Newcomet, *Radium and Radiotherapy*, 68.

books of this second period provided conversions from these older units to the curie. These four authors explained that making these conversions, and consistently stating radioactivity in curies, was necessary for accurate, scientific dosage.

In stark contrast to the first period, three of these four authors explained the procedures for measuring the strength of radium salts. Measurement, whether performed by the physician or by a scientist, was generally ignored in the first period; but Newcomet, MacKee, and Simpson discussed how physicians should use equipment created for physics and chemistry laboratories. All three authors favored the use of an electroscope as the most accurate form of measurement. The other commonly used methods relied on qualitative comparisons of the salts' fluorescence or ability to expose a photographic plate. The advantages of these methods, as Newcomet pointed out, were that the photographic method gave permanent results, and both were easier for a physician untrained in physics to carry out; but he strongly supported the use of an electroscope. He urged his readers that the fluorescent and photographic methods should not be used "for any serious consideration."[246] Using an electroscope allowed the operator to make a direct quantitative comparison of the ionization of their unknown

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[246] Ibid., 75, 85.

sample to a known standard, and then express the activity of their sample in curies.[247] Both Newcomet and MacKee considered it necessary for a radium therapist to enlist the assistance of a physicist in making measurements with an electroscope. MacKee explained that using an electroscope was "exceedingly technical and subject to many errors."[248] Newcomet recommended to his readers that a physicist should be "subjected to several crucial tests before they are accepted" to measure the therapeutic salts.[249] A radium therapist should, therefore, reach out to a competent physicist to measure their radium before embarking on clinical work, and, if he did not feel comfortable using physics laboratory equipment, continue to rely on the physicist to verify the strength of his radium preparations on a regular basis. This is a dramatic change from the experimental period of radium therapy, where texts generally ignored measurement and did not discuss direct collaboration with physicists.

Not all of the units which had been used in the medical literature could be directly converted into curies—and in these cases, the authors could only emphasize their ambiguity and encourage their readers to use the curie in their own work. Therapeutic

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[247] Newcomet gave the most detailed explanation of how to make measurements with an electroscope, including the need for quiet and stillness when measuring so as not to disturb the precise instrument, and the requirement that the electroscope be stored in old lead (old so that there would be no radio-lead present) to keep out any extraneous environmental radioactivity. Ibid., 78. MacKee, on the other hand, did not understand this ionization method and claimed that "until every applicator from every manufacturer is the same in all details the ionization method cannot be used to standardize dosage." Instead, "until some uniform method of measurement and manufacture is worked out it is preferable for the radiologist to standardize his own applicators under varying conditions on his own person." This created a standard "erythema dose" based on the physician's own reactions to radium, and was a method developed in the early days of roentgen therapy. MacKee's inclusion of it in his text demonstrates how much more comfortable and experiences he was with X-rays than with radium. MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, 197.

[248] MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, 176.

[249] Newcomet, *Radium and Radiotherapy*, 85.

units such as the milligram minute, the milligram second, the milligram hour, volts per hour, and volts per minute were common in the medical literature of the first period, and were calculated by multiplying the milligrams of radium applied (or the voltage of an X-ray tube emitting an equivalent activity strength) by the time of application. These units attempted to fully quantify the dosage in one unit, but, as MacKee pointed out, they were "an inaccurate way of expressing dosage ... [unless] all the details of treatment" are given.[250] Besides implying an equivalence between 100 mg. applied over one minute and 1 mg. applied over 100 minutes, these units do not include essential information like the activity of the salts, the filtration used, or the distance between the radium and the skin. MacKee also discussed the French and English use of flat varnish applicators and their definition of a standard "full strength" applicator as a unit. This left much to be desired, as some accepted 5.3 mg. of radium element per square centimeter as full strength and other 5 mg. per square centimeter; furthermore, manufacture of these varnish applicators was not standardized, with variations in thickness and varnish composition present.[251] Physicians in this second period, because of their greater familiarity with and reliance on physics, realized the failings of medical units introduced in the first period.

Newcomet and MacKee also emphasized the scientific necessity of quantifying radium salts in terms of the amount of radium element they contained, and not merely in terms of their mass, as was standard in the first period. Giving just the mass is imprecise,

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[250] MacKee, *X-Rays and Radium in the Treatment of Diseases of the Skin*, 184.

[251] Ibid., 190–191. MacKee, however, did support a new medical unit: the radion, proposed by Memorial Hospital physicist Gioacchino Failla. The radion, unlike the earlier medical units, was scientifically informed, "by means of plotted absorption, intensity and distance curves." Ibid., 184. The radion expressed the radioactive intensity delivered to tissues at any depth below the surface. MacKee considered the radion "ingenious" but not yet "given a thorough practical test." Ibid. The radion was ultimately not accepted as a unit.

they explained, because different salts contain different amounts of radium element—1 milligram of radium bromide is less active than 1 milligram of radium sulphate, for example, because it contains less radium element. Newcomet provided his readers with a table converting total mass to the mass of radium element present for the four radium salts used therapeutically.[252] Without this adjustment in how the mass of radium salts were given in medical literature, stated dosages would be imprecise—and it was scientific considerations that illuminated this imprecision.

Physicians, and the authors of these books, extended this period's interest in quantitative measurement to all aspects of dosage. They identified several variables specific to the chosen applicator that needed to be understood. Newcomet enumerated these for his readers:

> 1. The activity of the radio-active salt.
> 2. Weight of the salt and the proportion of impurities therein contained.
> 3. Impurities.
> 4. Surface and size of the grains of salt.
> 5. Distribution.
> 6. Age of salt.
> 7. The quality and quantity of the fixative substance or wall of a capsule.[253]

The radium therapist had to understand these variables before determining dosage. In addition to these factors specific to the applicator, there were additional variables critical to a complete understanding of the appropriate dosage, as MacKee explained. The duration of application, the time between sessions, filtration, and the distance between the applicator and the skin all affected the radioactivity delivered to the tissues. When these books discussed specific diseases or case histories, they included these dosage variables.

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[252] Newcomet, *Radium and Radiotherapy*, 36.

[253] Ibid., 120–121.

All of these variables could be exactly determined, their importance to accurate dosage was recognized because of radium therapists' greater interest in measurement in this period.

Physics had a greater influence on radium therapy in this second period. Physicians better understood the clinical implications of the differences between alphas, betas, and gammas, and of radium's decay chain. The establishment of the curie also provided an important improvement for dosage. This physics knowledge was directly connected to therapeutic considerations by authors in this period. These authors also realized the importance of accurate measurement and encouraged their readers to collaborate with physicists. Finally, these textbook authors, in contrast with those of the experimental period, made strong claims for the necessity of scientific expertise in radium therapy.

Radium Therapy Education

Gradually, as radium therapy was accepted by the medical community, more formal educational opportunities began to become available. In this section we will look at the radium therapy course notes of a nursing student and a radium therapy correspondence course for physicians to get a sense of these changes. Both of these courses emphasized clinical considerations, but were based on physics knowledge. From them we can see that nurses were not expected to understand scientific details, but that physicians were. The example problems in the correspondence course also give a sense of the calculations that were performed in the course of radium therapy—by the physician or by a physicist working with him. Radium therapy was becoming an accepted hospital therapy, and physics and physicists had important roles in this new location.

In 1925, Mildred Darragh was a nursing student at the Philadelphia General Hospital. The Hospital and its nursing school were run by the Philadelphia Department of Public Health's Bureau of Hospitals. Darragh learned about subjects including medical nursing, surgical nursing, psychology, anatomy, sanitation, and "diet in disease and radium therapy."[254] There was also a section on radium therapy: she took notes on three lectures from April 30 through May 15, and on an exam on May 18.[255] The inclusion of this topic demonstrates that radium therapy was becoming an accepted hospital therapy, and the content of her course shows the strong identification between radium therapy and cancer. The physics of radioactivity was not discussed in her course: it was not considered relevant for nurses to possess this scientific knowledge. They did, however, need to understand the clinical implications of that physics.

The radium therapy section focused exclusively on cancer patients, for whom "early operation and radiation is the only means of cure."[256] The nursing students learned

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[254] Lecture Notes of Mildred Darragh, Philadelphia General Hospital Student Nurse; Barbara Bates Center for the Study of the History of Nursing, University of Pennsylvania School of Nursing.

[255] Beginning in this professionalizing period, aspiring physicians interested in radium therapy could start to learn about it at some medical schools. For example, at the University of Minnesota, starting in 1927, there was a course offered on biophysics and radiation therapy, which had to be "limited to 12 hours" because of the demands on medical students' time with other courses. "Staff Meeting Report: History of the Radiation Therapy Section," K. W. Stenstrom, *The Medical Bulletin* June 8, 1956: 294; vertical file, Cancer Research #1 folder, University Archives, University of Minnesota, Twin Cities. Two years later, there were courses on roentgenology, radium therapy, and light therapy.

[256] Lecture Notes of Mildred Darragh, notes from April 30, 1925.

about current theories of the cause of carcinoma, and some basic facts about radium: that it was discovered by the Curies, that it was used therapeutically as a salt, that it was difficult to produce and that it was extremely expensive. "Radio activity is the power that certain elements have to penetrate matter opaque to ordinary light," Darragh's notes read—with no further information about the nature of radioactivity or its effects.[257] There were no notes on why radium was therapeutically useful or what effects it had on the body, which were common sections in texts of this period. What was more important was that physicians applied radium in tubes, filtered and unfiltered, and in external packs, and that when it was the nurse's duty to remove the radium, it be done promptly. In some cases, such as in uterine cancer, unfiltered tubes could cause hemorrhage and the nurse had to be prepared to attend to that. The main things Darragh and her classmates were taught to be mindful of with radium patients were: "cleanliness, medication, nourishment ... , kindness, watch for suicidal tendencies, and hemorrhage."[258] Nourishment was of importance so that radium therapy patients could maintain their strength after surgery and radiation; and these patients were under special observation for suicidal tendencies because of the serious, perhaps terminal, nature of their disease. These were all part of standard nursing practice at the time.[259] The end-of-unit exam questions that Darragh included in her notes emphasize the important aspects of the section: basic information about cancer and radium and practical details of caring for

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[257] Ibid., notes from May 15, 1925.

[258] Ibid.

[259] For a study of nursing in this era, see Patricia D'Antonio, *American Nursing: A History of Knowledge, Authority, and the Meaning of Work* (Baltimore: The Johns Hopkins University Press, 2010).

cancer patients. It was as important for a nurse to be aware of how radium was being applied and when it should be removed, by the nurse or by a physician, as it was to monitor carefully the radium therapy patient's general physical and mental well-being and to provide palliative care for those "hopeless cases."[260]

N. Ernest Dorsey provided a correspondence course for physicians interested in radium therapy, published as *Physics of Radioactivity.*[261] Dorsey was a Ph.D. physicist who ran the Radium Section of the National Bureau of Standards, and thus had some experience working, at least indirectly, with physicians as the Radium Section was responsible for verifying the activity of radium salts mailed in by radium therapists. "It is intended that the text shall be supplemented by correspondence," he told his readers in the preface, and explained that his treatment of the subject was "more expanded and colloquial in style than is desirable for a text intended for class room use."[262] The text was "as unmathematical as is consistent with the needs of the prospective student," but Dorsey included detailed equations when they were necessary (as, for example, when discussing radioactive decay).[263] He identified the proportion of space different topics received; interactions between matter and radiation and a practical discussion of

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[260] Lecture Notes of Mildred Darragh, May 18 exam questions.

[261] N. Ernest Dorsey, *Physics of Radioactivity* (Williams & Wilkins Company, 1921).

[262] Ibid., preface.

[263] Ibid., 1.

therapeutic considerations each received about a quarter of the text.[264] Throughout, he connected physics knowledge with clinical considerations, capped by the presentation of practical problems radium therapists would need to solve in their practice.

Dorsey presented his readers, overall, with a good introduction to the science of radioactivity and connected it to therapeutic concerns. He explained that radiation was the corpuscular and undulatory transmission of energy between bodies, and point source radiation followed an inverse square law. Though generally radioactive sources could be approximated as point sources, Dorsey included intensity curves for spherical, linear, and circular sources, like those that might be used in therapy. He discussed the interaction of radiation and matter: waves passing through matter are scattered and impart some energy into the matter, he explained, depending on the frequency of the undulation or the size of the corpuscles of the wave compared to the particles being struck in the material. "The primary effect of all kinds of radiations upon matter is to strain it, to set its constituents into vibration, and, frequently, to disrupt the material, or even to disrupt the elementary constituents of the material," he concluded.[265] This is not a clinical explanation of why radium was an effective therapeutic agent, but it does suggest how radioactivity, on a basic level, affects the body.

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[264] "The distribution of space is approximately as follows: (1) Discovery of radioactive materials and the development of the theory of radioactivity, 14 per cent. (2) Discussion of matter and radiation, and of the interaction of one on the other, 25 per cent. (3) Properties of the several radio-elements and examples of the methods by which they were discovered and their genetic relationships established, 14 per cent. (4) Standards and measurements, 9 per cent. (5) Practical applications and suggestions, 23 per cent. (6) Consideration of the dose, 9 per cent. (7) Tables and instructions for their use, 6 per cent." Ibid., preface.

[265] Ibid., 62.

As with other books in this second period, Dorsey discussed the decay chain of radium and its implication that radium salts must age before reaching their maximum production of therapeutically useful beta and gamma rays. Dorsey also raised the "interesting possibility" that radium D, emitting alpha and beta radiation with a half-life of around sixteen years, might stay in the human body after injection, ingestion, inhalation, or accident. "Whether the matter is of practical importance, or is merely a theoretical possibility, I am not prepared to say."[266] He does not speculate on the possible physiological effects of this potential long-term exposure—which, in later years, were found to be potentially fatal.

Dorsey also provided his readers with a scientific background for understanding the measurement and dosage of radioactivity, devoting three chapters to these considerations. He opened his chapter on the measurement of radioactivity by telling his readers that they should consult the literature for a full explanation, but gave a fairly detailed description of photographic and especially electrical methods. He told his readers to use the curie in their statement of strength in dosage, and provided conversions from old units to the curie. He also cautioned them to report the strength of their salts in terms of milligrams of "radium (element)," not as milligrams of "pure radium"—stating the weight of elemental radium in the sample avoided the need to specify the type of salt and its purity.[267]

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[266] Ibid., 133.

[267] Ibid., 170–171.

Physics knowledge was also important when purchasing radium for the clinic, and Dorsey spent a chapter outlining "suggestions to radium purchasers." [268] Salts should be purchased on the basis of their activity, not weight or purity, he counseled, because the activity is what is therapeutically useful and can be much more easily verified. Dorsey specifically recommended against buying radium based on its luminescence or on photographic measurements, as these were less precise.[269] "Above all things," he warned, "the purchaser should be cautious of very cheap radium. There is no such thing."[270] He recommended that purchasers require a guarantee from the producer that the radium salts are free from mesothorium (with its much shorter half-life), and that they send their new salts to be verified by National Bureau of Standards (NBS), through the program they offered to American users of radium, which he ran. This program effectively made physicists and a physics laboratory available to radium therapists, who mailed their salts to the NBS for testing.

Unique to *Physics of Radioactivity* is its final chapter, which provides eleven practical problems and their worked-out solutions. The problems are ones that the radium therapist would find useful: What is the intensity deposited on nearby tissue of beta and gamma radiation from the radium B and C in a small radon tube? How far should a point source of radioactivity be from the skin and how long should it be left there to deliver a specific intensity of radioactivity? These questions served to both reinforce Dorsey's major lessons in his text and to provide his readers with examples of

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[268] Ibid., 167.

[269] Ibid., 170, 169.

[270] Ibid., 169.

calculations they should carry out in the course of their radium therapy. It is impossible to know how comfortable most readers of Dorsey's book were in solving these problems; but in concluding his book with them Dorsey's implicit message was that he expected his readers to be able to solve them after studying the text—and that being able to solve these problems was an important aspect of being a responsible radium therapist.

The first problem Dorsey set for his readers was: "A radium emanation preparation (that contains no radium) was known to contain 50 mc. on January 15 at 10 a.m. How much emanation does it contain on January 20 at 2 p.m.?"[271] The problem is solved by using the decay equation for radium emanation; five days later, the tube would have less emanation in it, as it would have been decaying away, and this would change the activity of the tube. This was a calculation that physicians would have to understand, and would have to perform themselves if they had no staff physicist, in order to know the activity they should administer to a patient. In another problem, Dorsey asked:

> A very small glass bulb containing 5 mc. of radium emanation is buried in tissue that has a density of 1.25 gm./cc. If the bulb can be regarded as a point source, and if the absorption of the glass can be ignored, what is the intensity of (*a*) the hardest beta radiation from radium-B, (*b*) the hardest gamma radiation form radium-B, and (*c*) the hardest gamma radiation from radium-C, at points situation, respectively, at 1, 2, and 8 mm. from the center of the bulb?[272]

This, also, would be a calculation physicians should have been comfortable with as it was the basis for determining how strong a source should be embedded into a tumor, for example. The calculation was not complicated when the physician had reference absorption charts in front of him, like those provided in Dorsey's book. Dorsey's

[271] Ibid., 198.

[272] Ibid., 202.

problems, and the answers he worked out for them, both emphasized some of the clinical and physical points he made in the text and provided his readers with a reference for when they would make similar calculations in their practice.

Analyzing these courses and texts over the two periods of early American radium therapy demonstrates the changing ways physicians understood, appreciated, and used physics. Physicians began with an understanding of the basic science of radioactivity, but the relevance of this science to therapy was inconsistently explained and applied. Beginning in the second decade of the century, developments in physics and improvements in physicians' understanding of the physics of radium lead to better standards in dosage and measurement. Scientific expertise began to be expected of radium therapists, and they began to directly involve physicists in their clinical practice. This, in turn, led to moves into specialized practice and new settings for radiation therapy.

Chapter Four

The Rise of Hospital Physicists:

Growth and Professionalization of Radium Therapy

Introduction

In this chapter we will study the growth of American radium therapy from 1910 to around 1934. In this period, the measurement and dosage of radium were put on a more scientific basis, an American radium industry rose and fell, radium therapy gained enough attention and respect to be considered in the halls of Congress, and plants to collect radium emanation were introduced into the clinic by a physicist. At the same time as radium therapy was becoming more professionalized, radium therapists sought larger amounts of the element for therapy, in part because of the necessities of radium emanation plants. These plants also required expert personnel and dedicated space, and were a major factor in radium therapy's move from private practices to hospitals. Accompanying this move was the hiring of the first hospital physicists, who worked closely with physicians in managing and monitoring radium therapy. The chapter ends with a discussion of the growing awareness of the dangers of radium, for practitioners and patients, and analysis of how radiation therapy transitioned to the use of radioactive isotopes in the years after World War II. This professionalizing period of American radium therapy is characterized by the increased importance of physics to and involvement of physicists with American radium therapy.

This era is distinct in many ways from the period considered in chapter two. An international standard measure for radium was established in 1910, an American radium industry was established in the 1910's, and a new form of radon therapy was developed. These changes, especially the last, increased the involvement of physicists and motivated the move of radium therapy from the private clinic to the hospital. New discoveries in physics in the years 1932–1934—the discovery of the neutron, the invention of the cyclotron, and the discovery of artificial radioactivity—began to expand the possibilities of radiation medicine, opening a new era that really took off after the end of World War II. The beginning of this new era marks the end of the scope of this study.

Measurement and Dosage

In the first decade of the twentieth century, there was little consensus among American radium therapists on the measurement of radioactivity or on its dosage. This changed during the 1910s. Crucial to this change was the establishment of the curie as a unit of radioactivity by the scientific community. Through the efforts of physicists, it was also discovered that many medical samples of radium were much weaker than their owners believed. This professionalizing period of American radium therapy saw great improvements in both measurement and dosage—because both were placed on a more scientific basis.

A great advance in reaching a consensus on dosage was the establishment of an international standard for the measurement of radioactivity. At the International Congress of Radiology and Electricity in Brussels, September 13–15, 1910, a Radium Standards

Committee was founded. At their recommendation, the curie was defined as quantity of radium emanation in equilibrium with one gram of radium.[273] This is a measure of radioactivity because, as discussed in chapter two, when radium and radium emanation come into radioactive equilibrium, their activity is at a maximum, constant value. Marie Curie prepared the international standard, to be kept in Paris, and the committee arranged for Viennese chemist Otto Hönigschmid to prepare secondary standards, verified against the primary international standard, to be distributed to France, Germany, Austria, Britain, and North America.[274]

With the establishment of the curie as the standard unit of radioactivity in 1910, American radium therapists could now check their radium samples against standards that had been calibrated against the accepted international standard unit. Prior to this, when the activity of radium samples was measured with reference to the activity of uranium, it was more difficult for physicians to verify that the strength of radium they paid for was what they received. Using the curie, the activity of an unknown sample of radium salts could be determined directly by comparison with a known standard. As discussed in chapter three, there were three main methods available for the measurement of radioactivity before the curie: observing the effect of a sample on a photographic plate, counting the scintillations produced on a screen, or measuring the discharging of an electroscope. The photographic method was necessarily imprecise, as it required the

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273 A brief account of the debates of this committee over the amount of radium used to define the unit, and whom the curie is named after, is given in Paul W. Frame, "How the Curie Came to Be," Oak Ridge Associated Universities. Accessed February 19, 2013. Available from http://www.orau.org/ptp/articlesstories/thecurie.htm .

274 "Marie Curie and the NBS Radium Standards—1913: The U. S. Curie Standard," National Institute of Standards and Technology, www.nist.gov/pml/general/curie/1913.cfm, accessed on March 2, 2013.

visual comparison of the plate exposed to the sample with plate(s) exposed to salts of known activity. Scintillation was subjective, requiring close observation of small flashes on a screen in a darkened room.[275] Measuring activity with an electroscope was possible because radium salts ionize the surrounding air, and this method was the most reliable. The electroscope was charged, and then discharged by the unknown sample of radium salts as it was brought into the apparatus. The rate of discharge was compared to the rate of discharge of a known sample, and the ratio of these times would be the same as the ratio of their activities. Prior to the establishment of the curie, this activity was normally given in relation to the activity of uranium, and was usually on the order of 1,000; this meant that the stated activity was not as precise as its value suggested as there were usually only two significant digits. Additionally, before the establishment of the curie, the known sample could not have been compared to an established, accepted sample since there was no standard unit of measurement; so there was necessarily some uncertainty in whatever sample the unknown salts were being compared against.

After the establishment of the curie, the activity of larger samples of radium salts could be measured by comparing their gamma emission with that of a standardized sample. This also required the use of an electroscope, that was enclosed in a layer of lead thick enough to absorb all of the alpha and beta radiation produced (see Fig. 4.1). The observer measured the discharge of the electroscope's leaves produced by the unknown sample and the discharge produced by the standardized sample, and the ratio of these two

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[275] The difficulties of scintillation observations led to a famous debate on artificial disintegration between researchers at Vienna and Cambridge, leading centers of radioactivity research. This is studied by Roger Stuewer in "Artificial Disintegration and the Cambridge-Vienna Controversy," in *Observation, Experiment, and Hypothesis in Modern Physical Science*, Peter Achinstein and Owen Hannaway, eds. (Cambridge: MIT Press, 1985): 239–307.

measurements was the same as the ratio between their gamma activity. The sample's gamma activity could therefore be exactly determined from this ratio.[276] Some radium therapists reached out to physicists and asked them to create electroscopes for their clinics; but this was a delicate measurement best made by a physicist, knowledgeable about the details of radioactivity and trained in precision laboratory measurements. Generally, physicians had physicists make these measurements.[277]

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[276] For details, see C. H. Viol, "Some Units and Terminology Used in Radium & Emanation Therapy," *Radium* 1 No. 5 (August, 1913): 11.

[277] Howard Kelly hired a staff physicist in 1912, in part to help with these measurements; this was exceptional at the time, and we will discuss in detail later in the chapter how Kelly's uncommon wealth and commitment to radium therapy placed him at the vanguard of American radium therapy.

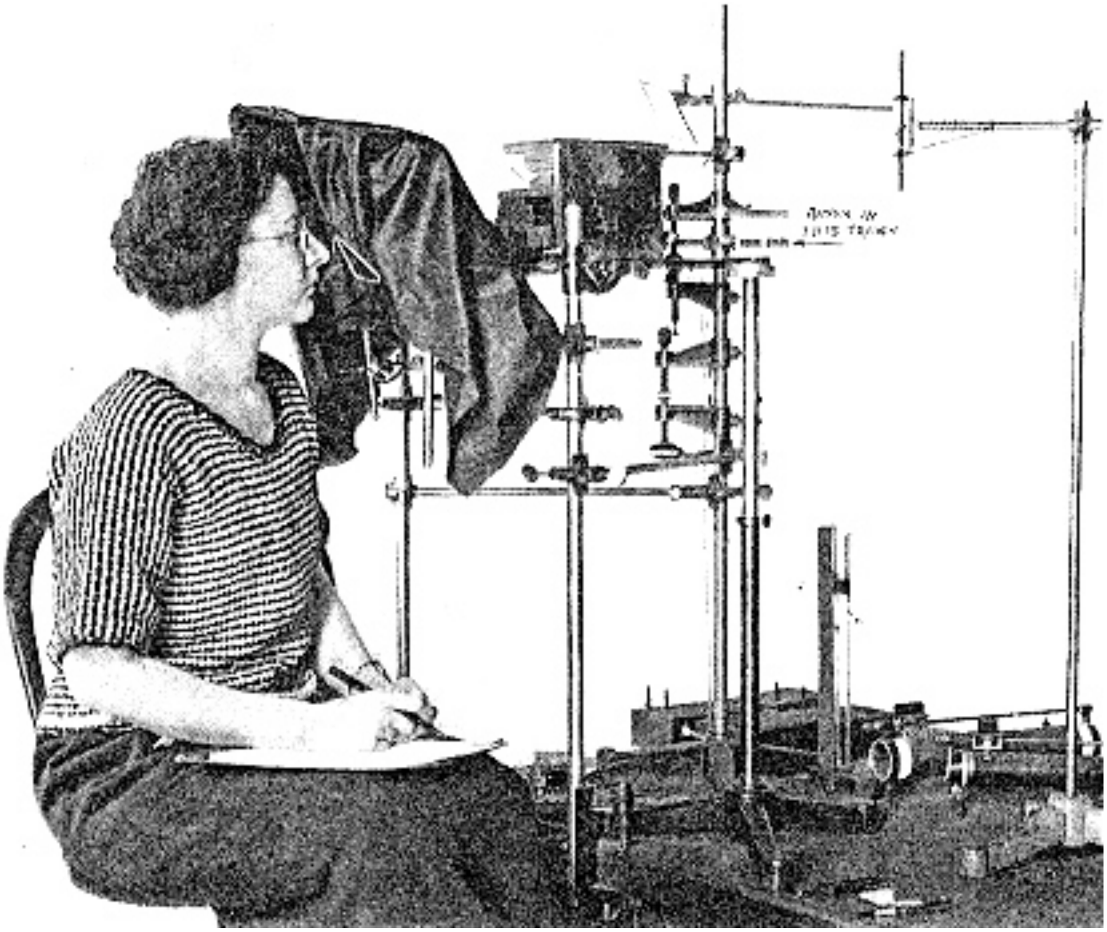

Figure 4.1. An unidentified scientist at the National Bureau of Standards using a gold-leaf electroscope. From R. C. Williams, "Preliminary Note on Observations Made on Physical Condition of Persons Engaged in Measuring Radium Preparations," Public Health Reports *38 (1923): Plate II.*

The National Bureau of Standards maintained their own standard sample of radium, prepared by the International Committee on Radium Standards after they established the curie. Starting in 1914 they offered a free service to verify the strength of radium preparations.[278] They tested around 500 radium samples, sent to them by

[278] "Marie Curie and the NBS Radium Standards—1913: The U. S. Curie Standard," National Institute of Standards and Technology, www.nist.gov/pml/general/curie/1913.cfm, accessed on March 2, 2013.

physicians and companies, until 1924, when they discontinued the program.[279] This was an essential way for physicians and clinics who did not have a physicist on staff to make necessary use of physicists' skills.[280]

When physicians started bringing their radium salts to be compared against a calibrated standard sample, many were surprised. One physicist who was asked to do such verifications especially remembered three samples that were brought to him: one tube of radium that was weak to the point of being useless; one sample of radium believed to contain 5.3 milligrams of radium element but was found to have less than 0.5 milligrams; and one tube that contained no radium at all. Based on his experience and conversation with the physicist doing similar measurements at the Bureau of Standards, he concluded that during the first decade of the twentieth century, "invariably these preparations ... were not what they claimed they were."[281]

The establishment of the curie was therefore crucial for radium therapists' knowledge of the strength of their radium. Being able to accurately determine the

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[279] After 1924 they continued to certify radium samples at the request of certain government agencies. Elmer H. Eisenhower, "Standardization: Where We Have Been and Where We Are Going," in Ronald L. Kathren and Paul L. Ziemer, eds., *Health Physics: A Backward Glance* (New York: Pergamon Press, 1980).

[280] In 1914, Bureau of Mines chemist Charles L. Parsons listed the places where a physician might get his radium verified against a radium standard: the Bureau of Standards, through this free service; through Standard Chemical Company, which sold radium preparations; or through the courtesy of Richard Moore or Samuel Lind in Denver with the Bureau of Mines, chemist Bertram Boltwood at Yale, physicist William Duane at Harvard, physicist George Pegram at Harvard, chemist Herbert McCoy at the University of Chicago, physical chemist Herman Schlundt at the University of Missouri, and chemist E. C. Franklin at Stanford. Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 350.

[281] Charles Viol in Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 109. This variability was because standards had not yet been established in production or in precise measurement.

gamma activity of a sample of radium salts also allowed the activity of that sample to be stated in terms of milligrams of pure radium element present in that sample. The amount of radium element in any given sample of radium salts depends upon the specific chemical formulation of the radium bromide or chloride salts, and the chemical purity of those salts. As we saw in chapter three, textbook authors in this period strongly argued for all radium to be given in terms of radium element present—and this did become the accepted practice.

The establishment of the curie was an important advance in the science of radioactivity and in radium therapy. It allowed for the discovery that many American physicians had weaker radium samples than they expected, and placed radium therapy dosage on a more scientific footing. It also made collaboration with physicists even more important for radium therapists, as they reached out for help with measurement of their radium samples.

The Standard Chemical Company and the Growth of American Radium Therapy

The Standard Chemical Company (SCC) began producing radium in 1913 and was the leading producer of radium in the American radium industry throughout the 1910s. This industry provided greater amounts of medical radium at comparatively lower costs. This supply of domestically-produced radium not only made radium more accessible for American physicians, and allowed them to use larger amounts in their practices, but transformed the nature of radium therapy. The company also changed the character of American radium therapy, by promoting internal radium therapy and by maintaining its own clinic and publishing a medical journal devoted to radium therapy.

Prior to the establishment of Standard Chemical, radium had to be purchased from European producers, mainly in France and Germany; and up to 1913, around 50% of this radium was refined from exported American ores.[282] The Standard Chemical Company was founded in Pittsburgh to produce medical radium preparations in 1911, and began refining in 1913.[283] Joseph Flannery, who ran a vanadium ore company with his brother, founded the company after losing his sister to cancer around 1910.[284] He had brought her

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282 Edward R. Landa, "A Brief History of the American Radium Industry and its Ties to the Scientific Community of its Early Twentieth Century," *Environment International* 19 (1993): 504. With the advent of the first World War, European imports of radium ceased, and the American producers stepped up their supply. Robison, "American Radium Engenders Telecurie Therapy During World War I," 1212. This radium was mainly produced by Standard Chemical, in Pittsburgh, and the Radium Company of America, in Sellersville, Pennsylvania. David Harvie, *Deadly Sunshine: The History and Fatal Legacy of Radium* (Stroud, Gloucestershire: Tempus Publishing, 2005): 97–8. As mentioned in chapter one, an entrepreneur had experimented with industrial radium extraction early in the first decade of the century, ultimately with no commercial production. Landa, "A Brief History of the American Radium Industry." During the war years, however, practically the only mining of American radium ores was undertaken by the National Radium Institute (which is discussed below); Standard Chemical was forced to practically cease mining operations and most of the radium salts it put on the market were produced from ores that had already been mined. "Scientific Notes & News: Radium," *Science* 43 (1916): 778–779. For statements from the Standard Chemical President Joseph Flannery on the running of his company during wartime, see: Congress, Senate, *Minerals and Metals for War Purposes: Hearings Before the Committee on Mines and Mining of the Senate on the Bill H.R. 11259,* 65th Cong., 2nd sess, May 2–29, 1918.

283 Robison, "American Radium Engenders Telecurie Therapy During World War I," 1212.

284 In 1930, U. S. Representative Clyde Kelly said that his "boyhood friend" Joseph Flannery had lost "several members of his family from [sic] cancer." Congress, House of Representatives, *Manufacture of One Gram of Radium: Hearing Before a Subcommittee of the Committee on Mines and Mining*, 71st Cong., 2nd sess, February 11, 25, and March 4, 11, 25, 1930: 3. The Flannerys' vanadium company used the element in strengthening steel; it is found in carnotite ore, which also contains uranium and radium. Flannery, through one of his companies, also marketed "Vanadiol," a "tonic" that was alleged to help in tuberculosis and pneumonia. When it was submitted to the AMA in 1911 for approval, the association asked to be provided with proof of the claims of the tonic's effects; two years later, the AMA discredited any claims of Vanadiol in their "Propaganda for Reform" section. Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 135. "Proprietary Vanadium Preparations," *JAMA* 60 No. 3 (January 18, 1913): 225.

to Europe in 1909 hoping that radium therapy would be able to help her.[285] The scarcity of medical radium in the United States, compared to the European supply, spurred Flannery to look into the possibility of refining radium ores in the United States.

As Maria Rentetzi has argued, the American radium industry, led by Standard Chemical, shaped radium research in America in the 1910's more than academia, largely by expanding the field of internal radium therapy.[286] Standard Chemical stopped production in 1921, largely because of the cheaper Belgian radium, mined from rich ores in the Belgian Congo, that began to appear on the market. Standard Chemical became a sales agent for the Belgian company until 1927 and was dissolved in 1933.[287] Over the course of its production, Standard Chemical refined around 80 grams of radium, and enjoyed the lion's share of the medical radium market in America.[288] There were a handful of other companies, most notably the Radium Company of America, based in

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[285] Joel O. Lubenau and Richard F. Mould, "The Vanadium Window, with Special Reference to Joseph and James Flannery's Contribution to the American Steel and Radium Industries," *NOWOTWORY Journal of Oncology* 58 (2008): 191e. Robison, "American Radium Engenders Telecurie Therapy During World War I," 1212. In response to either her illness or her death, in his own words: "In November, 1910, I was actuated by a motive to find out a cure for cancer. I sent a physician all over Europe for that purpose and kept him there six months, and he came back with the information that radium was being used over there, and they did not know the value of it yet; and that was the last thing they found out." Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 54.

[286] Maria Rentetzi, "The U.S. Radium Industry: Industrial In-house Research and the Commercialization of Science," *Minerva* 46 (2008): 437–462.

[287] Joel O. Lubeanu, "A Brief History of Standard Chemical Company," Oak Ridge Associated Universities. Accessed September 20, 2010. Available from http://www.orau.org/ptp/collection/miscellaneous/photoalbum/sscinfo.pdf.

[288] In Congressional hearings into the possibility of nationalizing radium, Standard Chemical was accused of having "a practical monopoly." Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 125.

Sellerville, Pennsylvania, but Standard Chemical was the first and the largest, and led the industry.

Standard Chemical maintained three radium standards; one was prepared by Stefan Meyer in Vienna, and the other two had been verified by Meyer's lab and Marie Curie's lab, respectively.[289] The company maintained a research laboratory and a free radium clinic in Pittsburgh. The laboratory was under the direction of radiochemist Charles Viol, and the clinic was led by physician William Cameron.[290] Standard Chemical investigated and promoted internal radium therapy in hope of expanding the market, and Cameron and Viol worked at the cutting edge of internal radium therapy research.[291]

Internal radium therapy was not as popular in the United States as it was in Europe, in part because of the stronger European tradition of hot spring treatments. It was discovered in the first decade of the century that many hot springs' waters are radioactive, and it was hypothesized that this might account for their purported healing properties.[292] Internal radium therapy was used in the United States, well before the establishment of the SCC, but it did not match its popularity in Europe. Standard

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[289] Ibid.: 110.

[290] Viol was hired immediately after he was awarded his doctorate in 1912 and led the laboratory starting in 1913; the director of the research laboratory in its first two years was Austrian chemist Otto Brill.

[291] For more, see Rentetzi, "The U.S. Radium Industry."

[292] For more on the varieties of internal radium therapy, see William H. Cameron and Charles H. Viol, "Classification of the Various Methods Employed in the Internal Administration of Radium Emanation and Radium Salts," *Radium* 4 No. 4 (January 1915): 57–68. Maria Rentetzi discusses how the American radium industry used this focus on internal therapy as a tool to expand the market in "The U.S. Radium Industry." Matthew Lavine studies internal radium therapy in and out of the clinic in *The First Atomic Age: Scientists, Radiations, and the American Public, 1895–1945* (New York: Palgrave Macmillan, 2013).

Chemical hoped to expand the medical radium market by increasing American interest in injection, inhalation, and ingestion of radium. Standard Chemical was not completely successful in raising American physicians' enthusiasm for internal radium therapy.

As part of his efforts to expand the boundaries of of radium therapy, William Cameron, director of the SCC's Free Radium Clinic, demonstrated medical practices that were questioned by contemporaries. In testimony before Congress on a bill considering the nationalization of radium, he explained how he exclusively selected patients who almost certainly had terminal cancers, especially cancers that had been little studied in the literature. He "brushed aside the superficial work," because this had been fairly well demonstrated to be an area where radium had great success.[293] Later in that hearing, John Anderson, director of the Hygienic Laboratory of the Public Health Service, criticized Cameron for selecting his patients purely on the basis of expanding the boundaries of experimental knowledge, rather than "find[ing] out what [radium] will do in the most favorable cases before we attempt to cure the cases that we recognize are moribund or practically hopeless."[294] Cameron was largely using internal radium therapy, introducing radium through inhalation, drinking, and injection. He told the committee that around two-fifths of his patients died as a cause of his treatments. Representatives James Byrnes and Joseph Howell wanted to know more about these deaths:

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293 Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 208.

294 Ibid., 224. Cameron's selection of patients was intentional, excluding patients whose cases he felt were already understood in the literature. This is different from the majority of radium therapists who, although many of their patients also had terminal cancers, had that patient pool not because of their selection but because their patients were those who were beyond the help of surgery.

> Mr. Byrnes: How long after you traeted [sic] them did they die?
> Dr. Cameron: From two to three weeks after I was through treating them.
> ...
> Mr. Howell: In those cases of internal cancer, how long would the patient have survived if he had not received any treatment?
> Dr. Cameron: Three or four months perhaps. I feel this way, that I have just shoved these patients over a little more quickly.[295]

Cameron likely would have chosen his words differently if he were preparing a written statement, but this candor is illuminating.

Frederick Proescher, director of the SCC's Lab for Experimental Therapy, was also involved with internal therapy. In 1914, he reported in the SCC's house journal on seven patients with hypertension he treated with radium injection. These patients were "selected by examining about 200 patients of an institution for the insane."[296] He found that five of the seven patients had their blood pressure decreased by the radium treatment. Laboratory and clinical results encouraged internal radium therapists to conclude that radium and radium emanation rapidly exit the body after administration.[297] It is now understood that radium plates permanently onto bones; when a radium solution is drunk,

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[295] Ibid., 209. Soon thereafter, Cameron expressed the opinion that business could produce radium preparations faster than government: "Dr. Cameron: I think, from what I know of commercialism and drug houses all over the country, that commercialism can put [radium] out ten times quicker than the Government can. Mr. Byrnes: If it is going to kill people, I think I should be opposed to putting it out as quickly as you want it." Ibid., 210.

[296] Frederick Proescher, "Influence of Intravenous Injection of Soluble Radium Salts in High Blood Pressure," *Radium* 3 No. 1 (April, 1914): 3. See also Frederick Proescher, "Influence of Intravenous Injection of Soluble Radium Salts in High Blood Pressure II," *Radium* 3 No. 2 (May, 1914): 17–21. 39 schizophrenic patients were also given radium injections at Chicago's Elgin State Hospital from 1930–1932. W.B. Looney, R.J. Hasterlik, A.M. Brues, and E. Skirmont, "A Clinical Investigation of the Chronic Effects of Radium Salts Administered Therapeutically (1915–1931)," *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 73 (1955): 1007.

[297] For example, Johns Hopkins physicians stated in 1913 that "the soluble salts of radium are rapidly excreted (four hours), no matter how administered." L.G. Rowntree and W.G. Baetjer, "Radium in Internal Medicine: Its Physiologic and Pharmacologic Effects," *JAMA* 61 (1913): 1438.

for example, 20% of the radium is absorbed by the body.[298] Another major American proponent of internal radium therapy was C. Everett Field, a New York physician who managed the SCC's New York office from 1915–1916.[299] From 1913–1921, Field made over 7,000 injections.[300] His clinical experience supported the general impressions of internal radium therapy, namely that it lowered blood pressure, increased red blood cell count, and rejuvenated "sexual powers."[301]

Despite the efforts of Standard Chemical to foster interest in internal radium therapy, and the excitement of practitioners like Field, the general medical community remained skeptical of it, even more so than of external radium therapy. This can be shown in part by a 1915 report of a Boston physician. He presented case histories of 42 patients he had treated with internal radium therapy, but felt that the positive results he saw did not speak for themselves. His insistence that "Radium internally is a real remedy! It is not inert!" demonstrates that his audience was inclined to believe that

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298 R. E. Rowland, *Radium in Humans: A Review of U.S. Studies* (Argonne, Illinois: Argonne National Laboratory, 1994). http://www.osti.gov/cgi-bin/rd_accomplishments/display_biblio.cgi?id=ACC0029&numPages=246&fp=N: 7.

299 To be precise, it was the New York office of the Radium Chemical Company, a subsidiary of Standard Chemical that mainly handled marketing. Legally the RCC and the SCC were distinct, in large part so that advertising efforts were kept distinct from medical efforts to technically satisfy expectations of medical ethics, but practically they operated hand in glove. Flannery had learned from experience with a vanadium patent medicine he sold through his Vanadium Chemical Company of the importance of following the medical profession's ethics guidelines. See "Proprietary Vanadium Preparations," *JAMA* 60 (1913): 225 and Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 124–135.

300 C. Everett Field, "Radium and Research: A Protest," *Medical Record* 100 (1921): 764. Abstracted in *Radium: Abstracts of Selected Articles on Radium and Radium Therapy, Compiled by American Institute of Medicine for United States Radium Corporation* (New York: Adams & Grace Company, 1922): 4.

301 C. E. Field, "Radium: Its Physio-Chemical Properties Considered with Relation to High Blood Pressure," *Medical Record* 89 (1916): 135. Abstracted in *Radium: Abstracts of Selected Articles on Radium and Radium Therapy*: 107.

internal radium therapy was *not* a "real remedy."[302] This belief was founded upon the lack of explanation for radium's purported clinical efficacy, and the fact that most patients treated with internal radium therapy were suffering from diseases like gout, rheumatism, arthritis, neuralgia, and neurasthenia: diseases that were known to be highly susceptible to show apparent improvement merely from psychological suggestion or from the healthy diet and exercise routine imposed by spa treatments that often accompanied internal radium therapies. In 1915, the AMA's Council on Pharmacy and Chemistry summarized the general consensus on internal radium therapy in its regular Propaganda for Reform column in *JAMA*. The Council was unimpressed with the evidence presented in favor of the therapy, and could not "express an opinion as to its value," in large part because of the difficulty to demonstrate the cause or permanency of improvement in most of the diseases treated with internal radium therapy. "There is moreover no convincing proof," they continued, "that radio-activity in mineral waters has any value."[303] Internal

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[302] Samuel Delano, "A Study in the Internal Therapeutics of Radium," *Radium* 6 No. 1 (October, 1915): 9. Reprinted from *Medical Record* 88 (1915): 137–143. Delano also protested that "to some, the glamour of laboratory tests being wanting, [these cases] may appear not complete—perhaps not scientifically precise. But there is still a large place for empiricism in medicine." Ibid., 8.

[303] "Radio-Rem," *JAMA* 64 (1915): 456. This article mainly focused on commercial internal radium therapy products, and were particularly harsh on these: "The proposition to make a mineral spring by placing a radium-bearing stick in a glass of water is another appeal to the belief in the mysterious."

radium therapy had its supporters in the 1910s and 1920s, but they were an embattled minority in American medicine.[304]

As another effort to spur medical interest in radium, Standard Chemical published a journal, *Radium*, that was available free to physicians. *Radium* mainly reprinted articles on radium therapy, from domestic and foreign journals, but also included original research. Around 10,000 copies of *Radium* were published monthly.[305] *Radium* was printed from 1913 through 1921. Fig. 4.2 demonstrates that the journal was originally intended to publish original research articles, but that as the journal continued it had to be sustained by reprinting articles from other journals. Over its run, a little over 50% of the articles published were reprints from other journals, and a little over 20% of articles were written by one of three authors employed by Standard Chemical.[306] This was not the only case of radium sellers blurring the line between marketing and medicine: pioneering radium producer Armet de Lisle, in Paris, opened a clinic in 1906 and published a radium therapy text; and in America, the Radium Company of Colorado published *The Radium*

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304 Physicians already involved with springwater spa treatments or with external radium therapy were those most likely to experiment with internal radium therapy. Curtis Burnam, longtime collaborator with leading American radium therapist Howard Kelly, remembered that there had been some possibility of using internal radium therapy at the Kelly Clinic (which, with the subsequent discovery of its potentially fatal long-term effects, he was relieved had not become reality): "[Joseph Flannery] offered to supply me with any amount of [radium for injection]. A Scotch ancestry, which had transmitted a considerable amount of caution, was, I think, in a large measure responsible for declining this offer. I am happy to say that none of my associates nor I ever used radium in this manner." Curtis F. Burnam, "Early Experiences with Radium," *American Journal of Roentgenology and Radium Therapy* 36 (1936): 448.

305 Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 63.

306 These were William Cameron, director of Standard Chemical's Radium Clinic in Pittsburgh, Charles Viol, the company's leading physicist, and Frederick Proescher, director of Standard Chemical's medical laboratory. Cameron and Viol were the editors of *Radium*.

Therapist and Frank Simpson's Radium Institute of Chicago published *The Radium Quarterly*.[307]

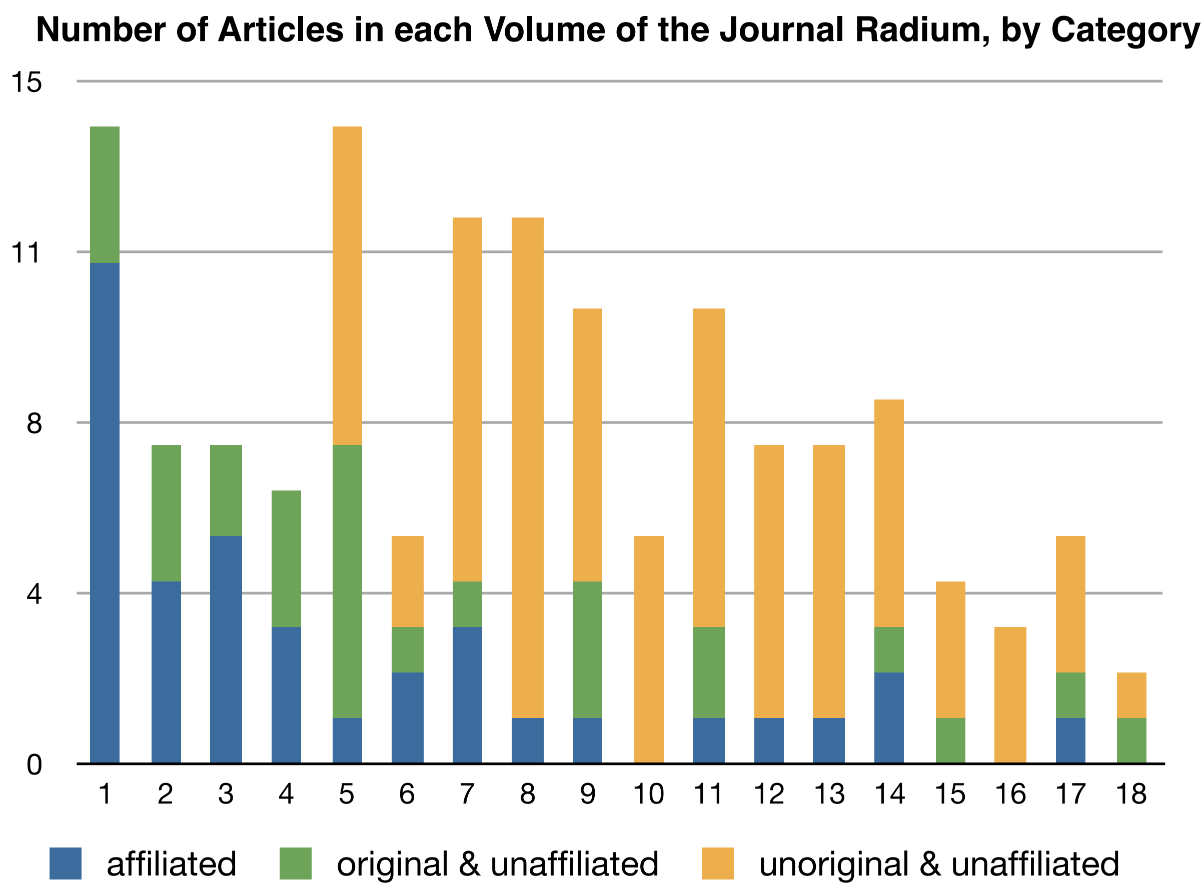

Figure 4.2. Articles written by William Cameron, Charles Viol, and Frederick Proescher, Standard Chemical employees, constitute the "affiliated" category. Volumes 17 and 18 also had fewer issues, condensing issues 4 and 5 into one issue; these years had five total issues rather than six.

At the 1916 meeting of the American Medical Society, the American Radium Society was established at the suggestion of Standard Chemical researchers. The ARS offered active membership to physicians, but physicists were eligible to become associate

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307 de Lisle: Landa, "A Brief History of the American Radium Industry," 504. *The Radium Therapist* was published two volumes, in 1922 and 1923, and is available via HathiTrust: http://catalog.hathitrust.org/Record/006705344. *The Radium Quarterly* published one volume, in 1917; the January and April issues are available on Google Books: http://books.google.com/books?id=QkugAAAAMAAJ.

members.[308] This was the first professional society of radium therapists, and its formation indicates both the field's growing acceptance in medicine and the importance of physicists to the field. As further evidence of the field's process of professionalization, in 1923, the *American Journal of Roentgenology* added "*and Radium Therapy*" to its name, after the ARS became associated with the journal.[309]

The Standard Chemical Company did more than just increase the American supply of medical radium. It raised the visibility of internal radium therapy, spurred the establishment of radium therapy's first professional association and created a medical journal dedicated to the field. Through those efforts—and the production of American radium—Standard Chemical fostered interest in radium therapy and aided its professionalization.

Memorial Hospital and Howard Kelly: Leaders in Radium Therapy

In this professionalizing period of American radium therapy, two centers appeared as the clear leaders of the field. One was a private urban hospital devoted to cancer care,

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[308] In the announcement published in the *Radium*, it was stipulated that "active membership in the society is to be limited to those holding a medical degree from a reputable medical school, and qualified for membership in the American Medical Association or the American Institute of Homeopathy, or its equivalent, together with sufficient experience in radium therapy." The difference between active membership and associate membership was not detailed. "The American Radium Society," *Radium* 8 No. 3 (December, 1916): 59. Beginning in 1919, physicians applying for active membership had additionally to report the amount of radium available to them and had to have treated at least 24 patients. Martin Colman and Roger F. Robison, "The American Radium Society: Its Origins and 90 Years of Contributions," *International Journal of Radiation Oncology, Biology, and Physics* 63 (2005): S385. Physicists were allowed to become full members in 1951. Ruth and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: The Williams and Wilkins Company, 1969): 445.

[309] The journal was created by the American Roentgen Ray Society. From 1952–1975, it was published under the name *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine*, after which it reverted to its original name, under which it is still printed.

New York City's Memorial Hospital (now Memorial Sloan-Kettering Cancer Center), the other was a large private clinic run by a gynecological surgeon, the Howard Kelly Clinic in Baltimore. Memorial Hospital and the Kelly Clinic established themselves as leaders in American radium therapy because of their unique financial resources and commitment to radium therapy.

In this period, radium therapy began to gain passionate supporters in the medical community, even though its ultimate efficacy was far from agreed upon and skepticism seemed to be the general consensus. One of these supporters was wealthy industrialist James Douglas. Douglas was president of mining company Phelps Dodge and had trained as a chemist; he had also lost a daughter to breast cancer in 1910. It was through her illness that he was introduced to radium therapy, and rented radium from Paris for her treatment.[310] Douglas began a collaboration with New York City pathologist James Ewing, whom he had met in 1907. Douglas made his first financial donation to Memorial Hospital in 1912, and in 1913, Douglas took Ewing on a tour of the radium therapy centers of Europe.[311] Despite not having a formal leadership position, Ewing had considerable power within Memorial Hospital, largely because of Douglas's support.

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310 Brecher and Brecher, *The Rays*: 271. This radium was rented through the *Banc du Radium*; American radium rental companies also appeared, which catered to physicians, and will be discussed later in this chapter.

311 James B. Murphy, "James Ewing: 1866–1943," *National Academy of Sciences Biographical Memoirs* 26 (1951): 48. Over the next 6 years Douglas donated around $600,000 to Memorial. Edward R. Landa, *Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry*, Colorado School of Mines Quarterly 82 (1987): 54. Murphy, "James Ewing," 49.

Through the influence of Ewing and Douglas, Memorial Hospital was rededicated as a cancer hospital in 1911.[312] The next year, Memorial appointed surgeon Henry Janeway as chief of cancer surgery and as chief of cancer radiotherapy. Ewing later recalled that Janeway's

> spirit of a scientific investigator ... was sometimes mistaken for eccentricity and ... he found some difficulty in securing immediate recognition in surgical circles. This situation made him available for the new field in cancer study which opened up when radiation therapy made its advent and called for radical changes in the orthodox surgical attitude toward this group of diseases.[313]

Janeway took his new appointment very seriously, and, realizing his lack of scientific preparation for the position, took night courses at Columbia University for two years to learn about radiation and radioactivity.[314]

Gynecological surgeon Howard Kelly was another one of the pioneers of radium therapy in America. Kelly was one of the "Big Four" founding physicians of Johns Hopkins Hospital, which opened in 1889. Kelly remained on the faculty until Hopkins made their appointments full-time in 1919, at which point he resigned to focus on his

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312 The hospital had been founded in 1887 as the New York Cancer Hospital, but was changed to be a general hospital, named the General Memorial Hospital, only two years later. Robison, "American Radium Engenders Telecurie Therapy During World War I," 1212–1216.

313 James Ewing, "Early Experiences in Radiation Therapy," *American Journal of Roentgenology and Radium Therapy* 31 (1934): 154.

314 Ibid. Janeway also had direct personal experience with cancer; he was diagnosed with a rare bone cancer in his jaw in 1905, and suffered from it, despite operations, until his death in 1927. In Ewing's opinion, this "stimulated the energy with which he approached all his problems, accounted for some of his radicalism, and nourished his strong hope that a cure for cancer must be provided, and indeed was just within reach." Ibid.

private practice.[315] Around 1904, Kelly obtained his first radium salts to treat an aunt who had cancer.[316] He was unable to save her, but remained interested in radium therapy. He was convinced of its value when leading Parisian radium therapist Louis Wickham visited Baltimore in 1907 and spoke about his experiences. Kelly began using radium in his private sanatorium, renamed the Kelly Hospital in 1912. Sometime after 1912, Kelly wanted to increase his supply of radium, and, in the words of his longtime collaborator Curtis Burnam,

> Dr. Kelly decided to purchase, if possible, a gram of radium. Having no financial responsibility, and a great longing to explore, his staff, of which I was the senior member, enthusiastically endorsed this move.[317]

Kelly was independently wealthy, and could afford to invest heavily in radium therapy. As Burnam related to a meeting of the American Radium Society in 1936, Kelly's interests were

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[315] There was great debate at the time over whether medical schools should continue to have part-time faculty, who also ran their own private practices, or if they should make medical faculty full-time so they could focus on their teaching responsibilities. In his influential 1910 report on medical reforms to the Carnegie Foundation, made at the request of the American Medical Association, Abraham Flexner supported the change to full-time positions. It was because of the Flexner Report that Hopkins made their faculty appointments full-time, despite the protests of some physicians like Kelly.

[316] Kelly acquired this radium from H. Lieber & Co., New York City importers. Letter of December 20, 1915 from H. Lieber & Co. to Howard Kelly, Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes, Box 7, Radium Correspondence—1914–1915 folder.

[317] Burnam, "Early Experiences with Radium," 447. H. L. Mencken, for whom the conservative, evangelical Kelly was a favorite target, took a different view of Kelly's wide-ranging enthusiasm, writing that "every now and then he would embrace some new scientific or pseudo-scientific fad, and pretend to a profound knowledge of the subject." H. L. Mencken, *Thirty-Five Years of Newspaper Work: A Memoir* (Baltimore: Johns Hopkins University Press, 2006). As an example of Kelly's extracurricular scientific activities, he was an avid amateur herpetologist, and kept a variety of exotic snakes and lizards in his study in his sanatorium. "Dr. Kelly Gives Up Snakes To Go in For Chuckawallas," *Baltimore Sun*, December 2, 1934. He even spoke on herpetology at one faculty meeting and was bitten by the rattlesnake he brought with him (which had been milked of its venom prior to the talk). Harry S. Sherwood, "Howard A. Kelly," *Baltimore Evening Sun*, September 19, 1928.

> very much wider than his professional bailiwick. He was interested in the discoveries of science in all fields, his enthusiasm for, and one might say, faith in, everything new, was immense and very infectious.[318]

By 1914, Kelly owned more than a gram of radium and was one of the most active radium therapists in the country.[319] The size of his clinic, which spread over four connected row houses in a fashionable section of Baltimore, put the Kelly Hospital more on the level of a hospital's radium clinic than the office of a private practitioner.

Kelly was set apart from many of his colleagues because of his strong Christian faith and evangelizing.[320] He volunteered his time in fights against prostitution and

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318 Burnam, "Early Experiences with Radium,", 438. Burnam stated that he had absolutely no intention of leaving surgical gynecology after graduation from Johns Hopkins, and "as to what brought about the change [to practice radium therapy], it can be summarized in one word—'Kelly.'" Towards the end of his career, Kelly was greatly enthusiastic about electrosurgery; see Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes, Box 16, Scientific Notes—Radium-Electrosurgery folder.

319 This gram of radium came from a variety of suppliers, but a significant portion came from the SCC. Kelly's holdings would increase over the next few years as he received radium from the National Radium Institute, as discussed later in the chapter.

320 Kelly commented on his feelings of uniqueness in his evangelical faith in his journal, in an entry on January 18, 1914: "I have known my Hopkins colleagues for a quarter of a century yet not one of them has eve seemed to invite a simple earnest conversation in the hope of the life to come to which we are all nearing so rapidly. It seems to me they look on me as a religious crank, one who has very positive fixed opinions for wh[ich] no good reasons can be given [and] with whom it must therefore be unpleasant to talk on these subjects. But I do not believe they discus [sic] them with one another in my absence." Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes, Box 25, Folder 6: Jan–Feb 1914 j.

liquor and lobbied for the protection of Sunday as a day of rest.[321] He brought his faith to all aspects of his life, including his views on radium. A little over a week before Kelly addressed Congress on the possibility of nationalizing American radium ores (as will be discussed below), he spoke to the Bible Teachers' Training School in New York City and declared that medical radium was the fulfillment of Biblical prophecy, namely Malachi 4:2: "But unto you that fear my name shall the sun of righteousness arise with healing in its wings; and ye shall go forth, and gambol as calves of the stall."[322] This passage, to Kelly, captured the light-giving and healing powers of radium, and its ability to enact nearly miraculous cures. Many newspapers quoted from this address; the *New York*

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321 These efforts, and his fame as a surgeon, brought Kelly to the attention of Baltimore journalist H. L. Mencken, who often turned his pen against Kelly. Mencken was, in turn, at the top of Kelly's list of men to pray for. Marion Elizabeth Rodgers, *Mencken: The American Iconoclast* (Oxford University Press US: 2005): 151. See also Charles Stewart Roberts, "H. L. Mencken and the Four Doctors: Osler, Halsted, Welch, and Kelly," *Baylor University Medical Center Proceedings* October 2010 (http://findarticles.com/p/articles/mi_6802/is_4_23/ai_n56337490) and Mencken's writings on Kelly in H. L. Mencken, *Minority Report: H. L. Mencken's Notebooks* (Baltimore: Johns Hopkins University Press, 1956): 89–90 and Mencken, *Thirty-Five Years of Newspaper Work*. Mencken mentioned Kelly several times in his famous coverage of the Scopes trial, including the following: "Dr. Kelly should come down here and see his dreams made real. He will find a people who not only accept the Bible as an infallible handbook of history, geology, biology and celestial physics, but who also practice its moral precepts ... I propose that Dr. Kelly be sent here for sixty days, preferably in the heat of summer. He will return to Baltimore yelling for a carboy of pilsner and eager to master the saxophone." H. L. Mencken, "Trial as Religious Orgy," *Baltimore Evening Sun* (July 11, 1925), as reproduced by the Internet Archive, http://archive.org/details/CoverageOfTheScopesTrialByH.l.Mencken, accessed on February 28, 2013.

322 Malachi 4:2 English Revised Version.

Times reported on Kelly's speech on the second page.[323] Such public preaching about radium was not unheard of in the press; but coming from a physician, it was.[324]

Financial resources were key for the Kelly Clinic and Memorial Hospital to acquire large amounts of radium and to position themselves as the leaders of American radium therapy. It would have been impossible for Kelly to become the radium therapy pioneer he was without his personal wealth; the radium used in his clinic was purchased with his own money. Similarly, Douglas's financial generosity was a necessary component of Memorial Hospital establishing itself as a leading American center of radium therapy. As greater amounts of radium became necessary for radium therapy, its cost was one of the reasons the therapy moved into hospitals. Another major reason being the necessity of hiring staff physicists and technicians to manage the growing stores of medical radium.

The cost of radium also had an impact on patients, of course. Medical costs in general could be steep, and radium therapy required the use of an element that was

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[323] "Fulfills Bible Prophecies," *New York Times* (January 9, 1914): 2. His interpretation of the passage is criticized by a Hopkins colleague in philology: Paul Haupt, "Radium in the Bible," *Johns Hopkins University Circular* 316 No. 6 (1919): 26–28. More immediate criticism, from a rector and a physician, is found in "Dr. Kelly's Parable," *New York Times* (January 12, 1914); another theological criticism is by T. S. Dolan, "Religion and Radium," *Baltimore Catholic Review* (January 24, 1914).

[324] For other examples of writings on radium and Christianity, see clippings from the William J. Hammer Collection of the Archives of the National Museum of American History: "Jesus, the Soul's Radium," *Farm & Friend* [Springfield, Ohio] (February 1, 1904), in Series 3, Box 61, Folder 1; "Radium Christians," *Boston Star* (February 4, 1904), in Series 3, Box 61, Folder 3; and "Radium and the Creator," *Elec. W. + Eng.* [unknown journal] (September 5, 1903), in Series 3 Box 62, Folder 3.

outside the financial means of many patients.[325] To get some idea of the expense of radium treatment, in the early 1920s radium salesman Frank Hartman wrote that some hospitals rented their radium applicators to their physicians for use in their private practices at a rate of 3¢ per milligram per hour.[326] For treatment using 100 mg. of radium, this would be around $38 per hour in today's money.[327] Many patients received radiation for more than one hour, and often sat for more than one session of radium therapy. This cost would only reflect external applications; radium preparations for surgical insertion would not be rented out, and surgical radium therapy would have carried a higher cost to the patient. Additionally, the hourly rate given by the hospital included all the time the applicator was absent from the hospital, not just the time in use in therapy; and it does not reflect whatever additional charges the physician might include to recompense his time, facilities, etc.[328]

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325 Nancy Tomes finds that "by the late 1920s, the cost of treating a serious illness might amount to between 10 and 25 percent of a family's income" and that "in the interwar period ... for many Americans, the new medicine and surgery represented a luxury good; that is, it was a set of services affordable only by families in the top third of income levels." Nancy Tomes, "Merchants of Health: Medicine and Consumer Culture in United States, 1900–1940," *The Journal of American History* 88 (2001): 526–7, 529.

326 Undated typesheet, The College of Physicians of Philadelphia, Historical Medical Library, Frank J. Hartman papers, 1904–1907, Box 2, Series 3, Folder 4, Scrapbook 2.

327 The Inflation Calculator, westegg.com/inflation.

328 Historian Ronald Numbers gives us some idea of these costs: "A 1918 Pennsylvania study showed that physicians' fee ranged 'from fifty cents to $5.00 for an office visit' ... with hospital-ward beds costing from $10.00 to $14.00 a week. For workers supporting large families on $2.00 a day, such fees were often prohibitive." Ronald L. Numbers, *Almost Persuaded: American Physicians and Compulsory Health Insurance, 1912–1920* (Baltimore: The Johns Hopkins University Press, 1978): 2.

Some radium therapists, like Kelly, gave free treatments to patients who could not afford them, and charged those who could according to their means.[329] Once radium therapy moved into hospitals, hospital physicians treated their charity patients with radium therapy for free, as they did with other therapies, subsidizing the cost of their treatment with the fees they earned from paying patients. But the expense of radium may well have dissuaded some patients from seeking it out; and patients who lived in areas where there was no radium clinic would have to take on travel costs if they, or their referring physician, felt that radium therapy was the best course of action for them. In 1914, in a congressional report on the availability of radium, it was noted that "it has well been said, 'cancer is the poor man's disease and radium is the rich man's remedy.'"[330] Whatever the truth of this, it is important that during the 1910's radium therapy was perceived by many as a treatment only available to the wealthy.

Nationalized Radium?

Physicians or hospitals that desired radium could acquire as much as they could afford; this concentrated it mainly in a few centers, almost exclusively in large eastern cities. To some radium therapists, this was a situation in need of a remedy: to best serve

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[329] Kelly told Congress in 1914 that 50% of his patients were charity cases, paying little or nothing. Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914, 19. This was not the popular perception of Kelly's fees, or indeed those of surgeons generally. According to H. L. Mencken, Kelly was in particular "notorious for his extravagant fees. He invented the system of charging a husband a month's income for an operation on his wife. ... His hospital was expensive otherwise, and in consequence nine-tenths of his patients were the wives of wealthy men. It was reported that he not infrequently demanded and got a fee of $10,000." Mencken, *Thirty-Five Years of Newspaper Work,* 35.

[330] Report No. 214, House of Representatives, 63rd Congress, 2nd Session, 9.

suffering mankind, they reasoned, would it not make more sense to have the government create radium centers spread throughout the country to ensure a fair distribution of the element and make radium therapy available to the largest number of people? Such public radium institutions could also act as a vehicle for ensuring that safe, rational, and responsible radium treatments were given. These institutions would also serve to consolidate experts, both physicians and physicists, and, as we saw in chapter three, training in radium therapy was not standardized and such central locations would be valuable educational centers. At the very least, these radium therapists argued, the national government ought to consider stopping the exportation of radium to conserve it for medical use in America. Other countries instituted some government control over medical radium. Starting around 1909, the Austrian government began to take possession of the country's radium ore and placed an embargo on its export, and the German government also regulated and controlled medical radium; Britain would decide in 1929 to nationalize the control and distribution of medical radium.[331] In 1914, radium therapy was important enough in the United States that the government considered placing American radium ores in the public trust so that they might be conserved for therapeutic use.

As early as 1912, the U.S. Bureau of Mines, which had been created in 1910, became aware of the fact that America was exporting its radium ores abroad and then

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[331] David Harvie concentrates on radium therapy in Britain in *Deadly Sunshine.* The *Radiumhemmet* in Stockholm was an international leader in radiation therapy, and by 1925 was sponsored by the national and municipal governments. For more, see Dimitrios Kardamakis, Evi Gustavson-Kadaka, Ekaterini Spiliopoulou, and Sten Nilsson, "The History of Radiumhemmet in Stockholm in the period 1985–1950: The Transformation of an Outpatient Clinic to an Academic Department," *Vesalius* 16 (2010): 95–99.

purchasing prepared radium salts.[332] They began investigating what might be involved with government production of medical radium. At the same time, Howard Kelly and James Douglas, whose wealth and interest in radium therapy were exceptional, began collaborating in the creation of the National Radium Institute (NRI), with the goal of producing radium, at a cost lower than the market price, for medical use and research. The NRI was incorporated in September of 1913, and the next month they signed an agreement with the Bureau of Mines, under which the Bureau would provide scientists and engineers and the NRI would provide $150,000, over three years, towards the refining of radium.[333] The NRI would retain the first 7 grams of radium produced, and

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[332] Charles L. Parsons, R.B. Moore, S.C. Lind, and O.C. Schaefer, "Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite," Bulletin of the U.S. Bureau of Mines 104 (1915): 7.

[333] $150,000 in 1913 represents around $3.4 million in today's money. The Inflation Calculator, www.westegg.com/inflation.

any salts produced over that would go to the Bureau.[334] Practically, this meant that Kelly and Douglas put up $150,000 of their own money, and would split the first 7 grams of radium between the Kelly Clinic and Memorial Hospital.

For simplicity, I will refer to this collaboration between the National Radium Institute and the Bureau of Mines simply as the NRI, since the Institute practically did not exist outside of the collaborative effort. The NRI leased carnotite mining claims in Colorado (carnotite being the most common and economical radium ore in America), and set up a plant in Denver. Charles Parsons was Chief of the Division of Mineral Technology of the Bureau of Mines and in many ways led the NRI efforts; also important were chemists Richard Moore and Samuel Lind.[335] The NRI was successful, producing

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[334] "National Radium Institute, 500 South Santa Fe Drive, Denver, Denver County, CO," Library of Congress Historic American Buildings Survey / Historic American Engineering Record / Historic American Landscapes Survey. Accessed February 20, 2013. Available from http://www.loc.gov/pictures/collection/hh/item/co0204/. Parsons et al., "Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite." Burnam's later recollection that the NRI was incorporated at the suggestion of the Bureau of Mines after the failure of the 1914 bill to nationalize radium ore is erroneous. Burnam, "Early Experiences with Radium," 448. It is possible that, although Kelly wrote the letter to the Bureau suggesting the collaboration, the idea for the NRI originated with the Bureau of Mines. The Bureau's main report on the Institute contains an unfortunate omission that makes this point ambiguous: "the bureau ascertained that Dr. Howard A. Kelly, of Baltimore, Md., and Dr. James Douglas, of New York City, were deeply interested in the production of radium for use in two hospitals with which they were closely connected. The suggestion was made them [sic] that they form a radium institute and endeavor to work up some of the American ores and keep the radium in this country for use among our own people." Parsons et al., "Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite," 8. Maria Rentetzi credits the formation of the NRI to Charles Parsons of the Bureau of Mines: Rentetzi, "The U.S. Radium Industry," 441–442. A 1914 article in *Mining and Scientific Press* by Douglas's nephew, one of the directors of the NRI, states Parsons approached Kelly and Douglas with the idea of the NRI. Archibald Douglas, "The National Radium Institute," *Mining and Scientific Press* (January 5, 1914), quoted in Congress, House of Representatives, Report No. 214, 63rd Cong., 2nd sess. In 1914, Joseph Holmes, Director of the Bureau of Mines, says that the idea of the NRI was conceived when he went to his friend Douglas for advice on the American supply of radium. Congress, Senate, *Radium: Hearing Before the Committee on Mines and Mining of the U.S. Senate on S. 4405*, 63rd Cong., 2nd sess., February 10–24, 1914: 156.

[335] Lind had studied with Curie, and after leaving the NRI went on to be a leading researcher in radiation chemistry.

8.5 grams of radium by the time it closed its plant in 1917.[336] The Bureau patented their production process and allowed its free use "by anyone who cares to use it for the benefit of the American people."[337] It was reported that the NRI was able to produce radium for about $40,000 per gram, which was approximately one-third its current market price.[338]

The supply of medical radium in the United States did not meet the demand, and this inadequacy and the success of the NRI drew national interest; in 1914 Congress considered a bill that would nationalize the country's radium ores.[339] In the hearings for this bill, radium therapists strongly supported its enactment, arguing it would allow for better treatment of American cancer patients. Howard Kelly, Robert Abbe, and other physicians spoke in a hearing before the Committee on Mines and Mining of House of Representatives in favor of the bill; miners and industrialists, including Joseph Flannery of Standard Chemical, spoke out against it. Summarizing what he saw as the possible future of radium therapy, Abbe told the committee:

> If [radium] is not conserved, it will be sold everywhere by the makers who have the ware to sell, and it will be bought up by doctors all over the

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[336] "National Radium Institute, 500 South Santa Fe Drive, Denver, Denver County, CO," Library of Congress Historic American Buildings Survey / Historic American Engineering Record / Historic American Landscapes Survey. Accessed February 20, 2013. Available from http://www.loc.gov/pictures/collection/hh/item/co0204/.

[337] "Main Line of Railroad from Denver to Colorado Springs," *Bulletin of the U.S. Geological Survey* 707 (1922): 23.

[338] This was reported in official government reports, as in ibid. and Parsons et al., "Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite," 11, and in the popular press. This price did not include marketing costs, prospecting costs, and other expenses that would have been incurred by companies that the government did not have to shoulder.

[339] Under discussion were two related resolutions: H. J. Res. 185, introduced by Martin Foster (D–IL) and H. J. Res. 186, introduced by Scott Ferris (D–OK).

> country, who simply want to have a little as a toy, who do not know how to use it ... It will open up a fool's paradise.[340]

Radium therapy, in these physicians' view, required expert knowledge, both clinical and scientific. They firmly believed that more medical radium was needed in the country; Kelly himself wanted more even though his clinic had one of the largest stores in the world. They saw government management of radium ores as a way to make radium therapy available to the greatest number of American patients.[341]

The public vision presented by Abbe and Kelly felt like a government takeover of private holdings by the industrialists addressing the committee. Part of the industry's strategy for challenging the bill was to disparage the integrity and expertise of Kelly, who

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[340] Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914, 23.

[341] It is worth noting that the proposed government intervention would only extend to radium ores, and not to the supply and distribution of medical radium. Physicians may have been less enthusiastic about the bill had it been directly involved with medical practice. Ronald Numbers studies the American medical profession's opinion on government-mandated health insurance in *Almost Persuaded*, and finds that around 1916, "virtually all informed physicians seemed convinced that compulsory health insurance was inevitable," but this began to shift within a year, and by 1920, "scarcely a physician could be found willing to endorse such a 'socialistic' proposal." Numbers, *Almost Persuaded*: 50, xi.

was much in the public eye at the time.[342] The most vitriolic attack on Kelly was made by Barlow Willmarth, president of the Colorado Carnotite Company, which owned a large number of American radium ore deposits.[343] He "openly accused" Kelly of acting purely out of "mercenary motives:" of "most unethically" keeping his knowledge of radium therapy to himself, and of "beguiling" the Bureau of Mines into cooperating with his plans for the National Radium Institute.[344] Kelly had published little, if anything, in the medical literature about his work with radium, waiting until a sufficient period of time

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[342] A little over a month before the hearings, Kelly's and Abbe's names were in newspapers because of talks they gave before the College of Physicians of Philadelphia. The press distorted these talks into claims of radium as a cancer cure; see, for example, "Doctors Announce Sure Cancer Cure," *Trenton Evening Times* (December 17, 1913): 13. Moved to make a public statement to correct the record, Kelly wrote a long letter to the Philadelphia *Public Ledger*, which appeared as the article "Dr. Kelly Answers Criticisms on Radium Cure for Cancer," *Public Ledger* [Philadelphia] (December 28, 1913). A few weeks later, his lecture on radium as fulfilled biblical prophecy was picked up by the newspapers: "Fulfills Bible Prophecies," *New York Times*. Such publicity, especially the letter in the *Public Ledger* focusing on his therapy, overstepped the bounds of propriety the medical community expected of its members; self-promotion was a hallmark of quackery. The board of honor of the Medical and Chirurgical Faculty of Maryland therefore began to look into Kelly's activities with the press—and this was, in turn, reported in, for example, "Doctor Must Explain Newspaper Prominence," *New York Press* (January 11, 1914) and "Kelly's Friends Angry," *Baltimore News* (January 11, 1914). This was just a week before Kelly appeared in Congress. When Kelly left for Europe a few days after his testimony, this too was reported on: "Dr. Kelly Sails Suddenly to Europe," *New York Times* (January 25, 1914). The honor board prepared a report on Kelly, and while they found him "susceptible to certain kinds of publicity," no charges were made. "Kelly Report is Read," *Baltimore Sun* (January 31, 1914). Kelly was still in Europe, meeting with leading radioactivity researchers, when this report was read; he arrived back home the next week. "Large Party is Leaving Aboard the Lusitania," *New York Herald* (March 1, 1914), "The Lusitania Delayed by Blinding Snow Flurry," *New York Herald* (March 7, 1914).

[343] The *New York Times* reported that the company controlled "ore deposits from which nearly a half of the world's available supply of radium has been extracted." The overwhelming majority of the company's ore was processed in Europe. "Big Radium Owner Threatens a Strike," *New York Times* (January 16, 1914).

[344] In Willmarth's opinion, Douglas went along out of naïve philanthropic interests. Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 146, 159.

had passed before opining about the clinical cures he saw.[345] Implying that Kelly was surreptitiously behind the drafting of the bill, Willmarth raged, "he proposes to first strangle the present hope of humanity by withdrawing these [radium-bearing] lands from [commercial] entry, then embalming the corpse by delaying the possibility of getting radium made from the ores of these withdrawn areas, and then they propose to dissect the corpse of American patronage among themselves greatly to their own financial advantage."[346]

In his statements, Joseph Flannery explained to the Congressmen that Standard Chemical could, and did, produce radium more efficiently than the government did with the NRI.[347] He offered Congress an alternative to the bill: Standard Chemical would sell the government "200 g. of radium, which we figured is sufficient to treat every person in

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345 Kelly and Burnam published on their cases from 1909 onwards in a 1915 issue of *JAMA*, wanting to wait until sufficient time had elapsed for them to be able to comment on the health of some of their patients several years after treatment. Howard A. Kelly and Curtis F. Burnam, "Radium in the Treatment of Carcinomas of the Cervix Uteri and Vagina," *JAMA* 65 No. 22 (November 27, 1915): 1874–1878.

346 Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 145. For his own part, he answered the question, "Prospectors who oppose [the bill] are prompted solely by patriotic motives and the interest of humanity?" with "Absolutely." Ibid., 160. Wilmarth's outburst attracted the attention of the press, as well: "Assails Dr. Howard A. Kelly," *New York Times* (January 24, 1914): 4. Just before the hearings began, the *New York Times* reported that Wilmarth was so angered by the bill that he threatened that all American radium producers ought to shut down production immediately, and then if the bill were to pass, "mine our whole available supply in a single season and hold it for sky-high prices, which we will be in a position to force out of those who wish radium cures." "Big Radium Owner Threatens A Strike," *New York Times* (January 16, 1914).

347 Congress, Senate, *Radium: Hearing Before the Committee on Mines and Mining of the U.S. Senate on S. 4405*, 63rd Cong., 2nd sess., February 10–24, 1914: 23.

the United States who has cancer," at a price of $80,000 per gram of radium element.[348] Congress did not take him up on his offer.[349]

Importantly, a member of Congress was fighting a very public battle against cancer while this bill was under consideration in the House. Representative Robert Bremner (D–NJ) was under treatment in Kelly's clinic after consulting Kelly in December. The *New York Times* reported that Kelly and his collaborator Burnam did not hold much hope for being able to cure Bremner with radium, given the extent of the tumor, but were willing to make an attempt.[350] The House committee asked Kelly about Bremner's treatment in their questioning, and he told them he wanted a great deal more radium—10 grams—in order to be able to treat him as he wished.[351] The timing and publicity of Bremner's case made it seem like a test case for radium therapy.[352] After the House hearing had concluded, but before the Senate committee began their hearing on the

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[348] This price was twice what the NRI could produce radium for; but the NRI was not intended as a permanent production plant. For the government, it was a proof-of-concept test, and if its early success encouraged the government to investigate permanent involvement with medical radium through the introduction of this bill.

[349] Congress, Senate, *Radium: Hearing Before the Committee on Mines and Mining of the U.S. Senate on S. 4405*, 63rd Cong., 2nd sess., February 10–24, 1914: 19, 23. Radium salts contain from around 53%–79% radium element, depending on the chemical composition, so the total bill to the government would have been between $8 and $12 million. C. F. Whittemore, "Conversion Factors," *The Radium Therapist* Vol. 1 No. 3 (March 1922): 92–94. The total outlays of the US government in 1914 totaled $725 million; so that purchase would represent 1.1–1.7% of the total federal budget. Historical Federal Budget Reference: federal-budget.findthedata.org/l/16/1914.

[350] "Bremner's End Near: Gives Up All Hope," *New York Times* (February 3, 1914).

[351] Congress, Senate, *Radium: Hearing Before the Committee on Mines and Mining of the U.S. Senate on S. 4405*, 63rd Cong., 2nd sess., February 10–24, 1914: 9.

[352] One *New York Times* article explicitly labeled his case a test in a headline. "Scientists' Eyes on Radium Test," *New York Times* (December 28, 1913).

radium mining bill, Bremner died.[353] The Senators, naturally, wanted to ask about this: did Bremner's case have implications for the efficacy of radium therapy? Neither Kelly nor Burnam testified before the Senate committee, so the Senators questioned Joseph Flannery about Bremner. One Senator bluntly asked him: "Why couldn't you cure Representative Bremner?" to which Flannery responded, "They probably killed Representative Bremner with radium."[354] Because of the perceived failure of radium therapy in the test of the case of Bremner and the opposition of commercial mining interests, the bill failed.[355] Although the bill failed, it, along with the NRI, demonstrates the serious interest the U.S. government had in radium therapy, and the strong identification of radium therapy as a cancer treatment.

Expertise in Radium Therapy

The Congressional testimony demonstrates the importance of expertise and scientific knowledge in radium therapy and provides a rare record of leading radium

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353 In his last press report, as quoted in the *New York Times*, Bremner emphasized the great potential of radium in aiding cancer patients, and said "If experimenting on me has added a new fact to science, then my life has not been in vain, but has helped the race. My life is not worth one-tenth of the effort that has been put forth to save it. I am ready for the scrap heap, but feel that the cutting and the doctoring have added to the knowledge of how best to fight cancer. Some poor soul who comes after me may benefit." "Bremner Sends Message to Public," *New York Times* (January 12, 1914).

354 Congress, Senate, *Minerals and Metals for War Purposes: Hearings Before the Committee on Mines and Ming of the Senate on the Bill H.R. 11259,* 65th Cong., 2nd sess, May 2–29, 1918: 27. In a statement three days later, Flannery asked that that statement be changed to "Probably too much radium was applied in the hope of saving Mr. Bremner's life." Ibid.: 117. It is also worth noting the Senator's use of "you"—including everyone involved with radium therapy, even indirectly, into one category—and Flannery's use of "they," distancing himself from those actually involved with Bremner's treatment.

355 For a discussion of this debate and its relation to the radium industry, see Maria Rentetzi, "The U.S. Radium Industry."

therapists discussing their field. The physicians speaking before Congress made strong statements on the necessity of expert clinical and scientific knowledge in radium therapy.

Robert Abbe, especially, was extremely critical of physicians who, uneducated in the science of radium and the methodology of radium therapy, "fake it ... and if they go and buy 5 or 10 milligrams [by 1914 understood to be too small an amount to be useful therapeutically] for $1,000, they think they have everything and they make very absurd use of it."[356] This was a cornerstone of Abbe and others' support for government management of radium: on the free market, there was nothing to keep any physician from buying a small amount of radium, and, in fact, radium companies would be economically incentivized to sell small amounts of radium like this as well as fill the large orders of experts with financial resources like Kelly and Abbe. As long as radium therapy remained popular, and the leaders of the field enjoyed success, it mattered little to radium companies if a physician bought only 5 or 10 milligrams and subsequently were unable to help many of their patients with it. Government control of radium, then, would be a way not only to ensure that American radium stayed in the country, but also a way to concentrate medical radium in expert hands. In a 1930 hearing before a subcommittee of the House Committee on Mines and Mining, on a bill proposing the government produce a gram of radium for Veterans' Bureau hospitals, Kelly pointed out that government-run radium centers would also serve as important places for physicians to receive training in

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[356] Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914, 23.

radium therapy, which should take "about two years" before they would be prepared for using large amounts of radium in their own practice.[357]

Standard Chemical's leading physician, William Cameron, had a very different view of the situation.[358] Cameron was director of Standard Chemical's Radium Clinic in Pittsburgh, and had been hired by Standard Chemical after he approached the company for advice on radium therapy.[359] In stark contrast with the statements of Kelly and Abbe, Cameron felt that "the technique of [radium therapy] is very, very simple. Anybody can apply it with a few instructions."[360] In this, he completely dismissed the need for any understanding of physics or help from physicists.

Cameron reassured the committee that he did not allow Standard Chemical to sell radium preparations to quacks:

> Dr. Cameron: There is not a doctor in this country that could buy radium unless I first look up his record and see that he is all right. Then, they want some men to answer their letters—
> Mr. Hamlin: What do you mean by "all right"?
> Dr. Cameron: As to quackery, sir; that he is a reputable physician.
> Mr. Byrnes: Where do you get that from? The American Medical Association?

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357 Congress, House of Representatives, Subcommittee of the Committee on Mines and Mining, *Manufacture of One Gram of Radium: Hearing Before a Subcommittee of the Committee on Mines and Mining of the House of Representatives on H.R. 4811*, 71st Cong., 2nd sess., March 4, 11, 25, 1930: 56–57.

358 Cameron was technically not employed by Standard Chemical; rather, he was medical director of the Radium Chemical Company, a subsidiary of Standard Chemical that mainly handled marketing. Joseph Flannery legally was uninvolved with the Radium Chemical Company, but practically the SCC and RCC operated in tandem, to the extent that when testifying before Congress Cameron mistakenly stated that he was employed by Standard Chemical (and Flannery corrected him). Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914: 212.

359 Ibid.: 207.

360 Ibid.: 208.

Dr. Cameron: Yes, sir.[361]

This, however, did not address Abbe and Kelly's concerns. They were less concerned, in this instance, with radium in the hands of outright quacks than they are with radium being inadvertently misapplied by well-intentioned but uninformed physicians. Ultimately, this was a problem not to be solved by the government, but by radium therapists themselves. As the field of radium therapy gained legitimacy in the medical community over the next decade—through the establishment of the American Radium Society and dedicated medical journals—radium therapists were increasingly able to exclude inexperienced and uneducated practitioners from their professional circle and to set standards of clinical and scientific knowledge of radium as requirements for practicing as a radium therapist.

In the mid-1920s, new companies began to appear, offering the rental of radium preparations, usually at an hourly rate. This practice was aimed at hospitals and physicians interested in radium therapy who were unable to afford the purchase of radium. The problem that this presented, in the opinion of established radium therapists, was that radium rental put the element in the hands of inexperienced practitioners who knew nothing about the clinical or scientific facts of radium. Most of the radium rental firms advertised that they sent a complete set of instructions along with their radium preparations.

Experienced radium therapists, working in hospitals with a supply of radium and a staff physicist, deplored the advent of these rental firms. No set of instructions could stand in for clinical experience or an understanding of the physics of radium and

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[361] Ibid.: 211.

radioactivity. Philadelphia radium and radium products merchant Frank Hartman told an interviewer that

> I seldom ever sold radium to a private physician. My thought was always this, that one can read a book, and think he knows the answers, but that is not so with radium or radioactivity. For this reason, that if you don't understand the basic physical properties of radiation or the biological effects, leave it alone.[362]

Clinical experience was necessary for safe and effective radium therapy but it was not sufficient: radium therapists also needed to understand the basic physics of radium and radioactivity.

Individually, radium therapists were aware and appreciative of the importance of physicists to their field. Looking back in 1936, Curtis Burnam remembered that he was "already convinced that the most desirable field of human activities was in physics" when the NRI was in its beginning stages.[363] Writing in 1934, James Ewing was of the opinion that

> The advances [in radiology] have come, *first*, in the field of engineering, by which have been constructed more powerful, reliable and durable apparatus, and the provision of this apparatus on a wide scale. ... *Second*, we now know rather accurately what these machines and radium packs will actually deliver to the skin, and to every level of depth in the body and are thus able to prescribe dosage with assurance. ... *Finally*, most important and essential progress has come in a better understanding of the nature of the diseases to be treated with radiation, especially cancer.[364]

In radium therapy, the first two categories were due to the efforts of hospital physicists.

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362 College of Physicians of Philadelphia, Historical Medical Library, Frank J. Hartman papers, Box 4, folder 8, Interview between Frank Hartman and John Villeforth (1964).

363 Burnam, "Early Experiences with Radium," 449.

364 Ewing, "Early Experiences in Radiation Therapy," 161.

There were tensions between radium therapists and surgeons. Cancer was the field most associated with radium therapy, and cancer had been the exclusive purview of surgeons for generations. Radium therapists, in general, treated cancer patients who were beyond the help of surgery, either because of contraindications or the extent of the growth; however, the successes they found in many cases encouraged some to promote pre- or post-operative radiation in the hopes of checking recurrence. In 1914, Henry Janeway wrote, "All users of radium are most emphatic in expressing the belief that no operable cancers, except those of the skin, should be treated by radium in preference to operation."[365] This seems a fair assessment of the opinions of most radium therapists at the time, and they were "most emphatic" in this in part because of the pushback they sensed from surgeons.[366] The skepticism, and at times opposition, of surgeons towards radium therapy was not easily addressed.

The general medical community was also slow in its acceptance of radium therapy. In the early years of American radium therapy, medical journals occasionally published very critical articles on it, such as "Radium Therapeutics and Dangers" published in *Dietetic and Hygienic Gazette* in 1909. This article conflated X-rays and radium, crediting radium with the death of several roentgenologists.[367] In 1924, James Ewing felt that radium therapy had been "rapidly adopted," which "must stand as

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[365] H. H. Janeway, "Results of Radium in Cancer," *JAMA* 62 (1914): 1709.

[366] For more on this pushback, see Barbara Clow, *Negotiating Disease: Power and Cancer Care, 1900–1950* (Montreal & Kingston: McGill-Queen's University Press, 2001): 56 and Matthew Lavine, *A Cultural History of Radiation and Radioactivity in the United States, 1895–1945*, Wisconsin-Madison Ph.D. thesis, 2008: 141.

[367] "Radium Therapeutics and Dangers," *The Dietetic and Hygienic Gazette* 25 No. 3 (December, 1909): 707–708.

evidence of the intellectual honesty of the medical profession." However, he continued to say that:

> There is still an undercurrent of antagonism which reaches the public with much force, greatly impedes progress, interferes with the spread of knowledge, retards the acquisition of equipment and prevents many from receiving the benefits now available.[368]

The professionalizing efforts of radium therapists and radium therapy's move to hospitals did make radium therapy more accepted in this second period than it was in the first. In 1915, *JAMA* ran a supportive editorial on radium emanation plants and emanation therapy, and the 1921 AMA meeting featured several vendors of radium applicators and related equipment.[369] Radium therapy was becoming an accepted treatment in modern American cancer care.

Radium Emanation Plants and the Move to Hospitals

At the height of the success of the American radium industry, radium therapists began to use an elaborate new piece of medical equipment, the radium emanation plant. This apparatus was introduced into the clinic by physicist William Duane.[370] Radium emanation plants, adapted from the physics laboratory for use in the clinic, offered a

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[368] James Ewing, *Radium Report of the Memorial Hospital* (New York: Paul B. Hoeber, 1924). Quoted in Harold Swanberg, *Radiologic Maxims* (Quincy, Illinois: Radiological Review Publishing, 1932): 80.

[369] "Use of Condensed Radium Emanation in Glass Tubes," *JAMA* 65 (1915): 2181. "Radium: The Commercial Exhibit," *JAMA* 76 (1921): 1465.

[370] Duane credits physicist Ernest Rutherford and chemists William Ramsay, Frederick Soddy and André-Louis Debierne with with creating radium emanation apparatus that he modified. "Report of the Bio-Physical Laboratory to the Director of the Cancer Commission of Harvard University," quoted in Edward W. Webster, "The Origins of Medical Physics in the USA: William Duane, Ph.D., 1913–1920," *Medical Physics* 20 (1993): 1607–1610.

more effective and flexible therapy—one that required the hiring of physicists and the move of radium therapy from private practices to hospitals.

Duane worked for six years with Marie Curie in her laboratory. As part of this work in Paris, he was responsible for collecting radium emanation to maintain a comparatively pure sample of radium element.[371] Radium emanation is the gaseous element (now called radon) produced by radium as the next step in its decay chain, and can be pumped off a sample of radium. Duane designed an emanation plant modeled after those of Frederick Soddy and William Ramsay, Ernest Rutherford, and Paris physician André Louis Debierne. Duane sent the emanation he collected in capillary tubes to Paris radium therapists and instructed them in their therapeutic use.[372]

This experience made Duane the ideal candidate for Harvard's Huntington Hospital and the university's Jefferson Physical Laboratory when, in 1913, they sought to jointly hire a physicist to work with radiotherapy.[373] Duane accepted the position and was very probably the first hospital physicist in America.[374] Duane is perhaps best known for his research with X-rays and his contributions to the physics literature. Duane earned his Master's from Harvard in 1895, and was then awarded a Tyndall Fellowship from Harvard to complete undertake doctoral research from 1895 to 1897 with Max

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371 Marshall Brucer, "William Duane and the Radium Cow: An American Contribution to an Emerging Atomic Age," *Medical Physics* 20 (1993): 1601.

372 Ibid., 1602.

373 Duane was also a Harvard alumnus: he earned his bachelor's degree in 1893 and his master's in 1895.

374 For a biography of Duane, see Paul Forman, "William Duane," in *Dictionary of Scientific Biography*, Charles Coulston Gillispie, ed. (New York: Charles Scribner's Sons, 1990). Columbia University and the Standard Chemical Company also offered Duane positions at this time. Juan A. del Regato, "William Duane," *International Journal of Radiation Oncology and Biological Physics* 4 (1978): 720.

Planck at Berlin and Walther Nernst at Göttingen. After earning his Ph.D., Duane worked with Pierre and Marie Curie for several years.

Harvard's Cancer Commission wanted a physicist for the Huntington to manage their radium supply and their radium therapy. Early on, Duane worked directly with patients, deciding dosage and making radium applications.[375] In 1917, Harvard named him professor of biophysics, apparently making him the first physicist to hold that title at an American university. Duane's most important contribution to radium therapy was his improved version of the radium emanation plant, adapted for use in hospitals to collect emanation for medical use. This was a watershed moment in American radium therapy.

Radium emanation has a half-life of about three days, much shorter than radium's 1,600 years. This shorter half-life makes radon safer and more effective than radium in therapy, because it is closer in the decay chain to beta- and gamma-emitters and it will fully decay away in a fairly short period of time. (The decay chain of radium is discussed in chapter two.) Small glass "seeds" containing radium emanation could be surgically placed into the center of a tumor and left there permanently, avoiding the need for a second operation to remove them, as was the case when radium was surgically introduced into tumors. Radium emanation's half-life is around three days, so after around a week

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375 P. W. Bridgman, "Biographical Memoir of William Duane," *National Academy Biographical Memoirs* 18 (1937): 28. In the 1910's and 1920's, it was not unheard of for hospital physicists to interact with patients and give radium treatments. For example, physicist Karl Wilhelm Stenstrom at the University of Minnesota's Cancer Institute was very involved with patients; see for example Merle K. Loken, "Karl Wilhelm Stenstrom," *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 120 (1974): 472–474.

the emanation would be essentially depleted.[376] Radium emanation was also much less dense than radium salts of the same activity and could be contained in a much smaller container, which allowed for greater flexibility in the application and insertion of emanation.

Emanation plants, like the one shown in Fig. 4.3, relied on two mercury pumps (specifically, Toepler pumps, used in physics laboratories). The first pumped gases off of the radium, which was usually contained in a lead-lined safe for safety and theft protection. The radium was kept in solution and at least half a gram was needed for the emanation plant to be cost effective. The gases were pumped into a purification chamber, where chemical processes removed contaminating gases, mainly hydrogen and oxygen. The second pump removed the purified emanation from this chamber, and the emanation was then concentrated into capillary glass tubes.[377] These tubes needed to age for around four hours for emanation's daughter products to come into radioactive equilibrium, at which point the tube was at maximum activity. The tubes' activity would then be verified by a physicist, usually with an electroscope. This is a simplified sketch of the apparatus, but demonstrates why it required the daily attention of a staff physicist. Radium continually decays into emanation, so this "radium cow," as it was sometimes called, needed daily "milking" for the optimal production of tubes of emanation.

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[376] See chapter two for a discussion of the decay chain of radium; briefly, the next three elements in the chain after emanation have half lives of minutes, and then the chain sits at radium D, which has a half life of around twenty years, which in turn decays into two elements with half lives of days, the latter of which decays into lead, the final, stable element of the chain.

[377] For a detailed explanation of the workings of an emanation apparatus, see Frank Edward Simpson, *Radium Therapy* (St. Louis: C. V. Mosby, 1922): 29–33.

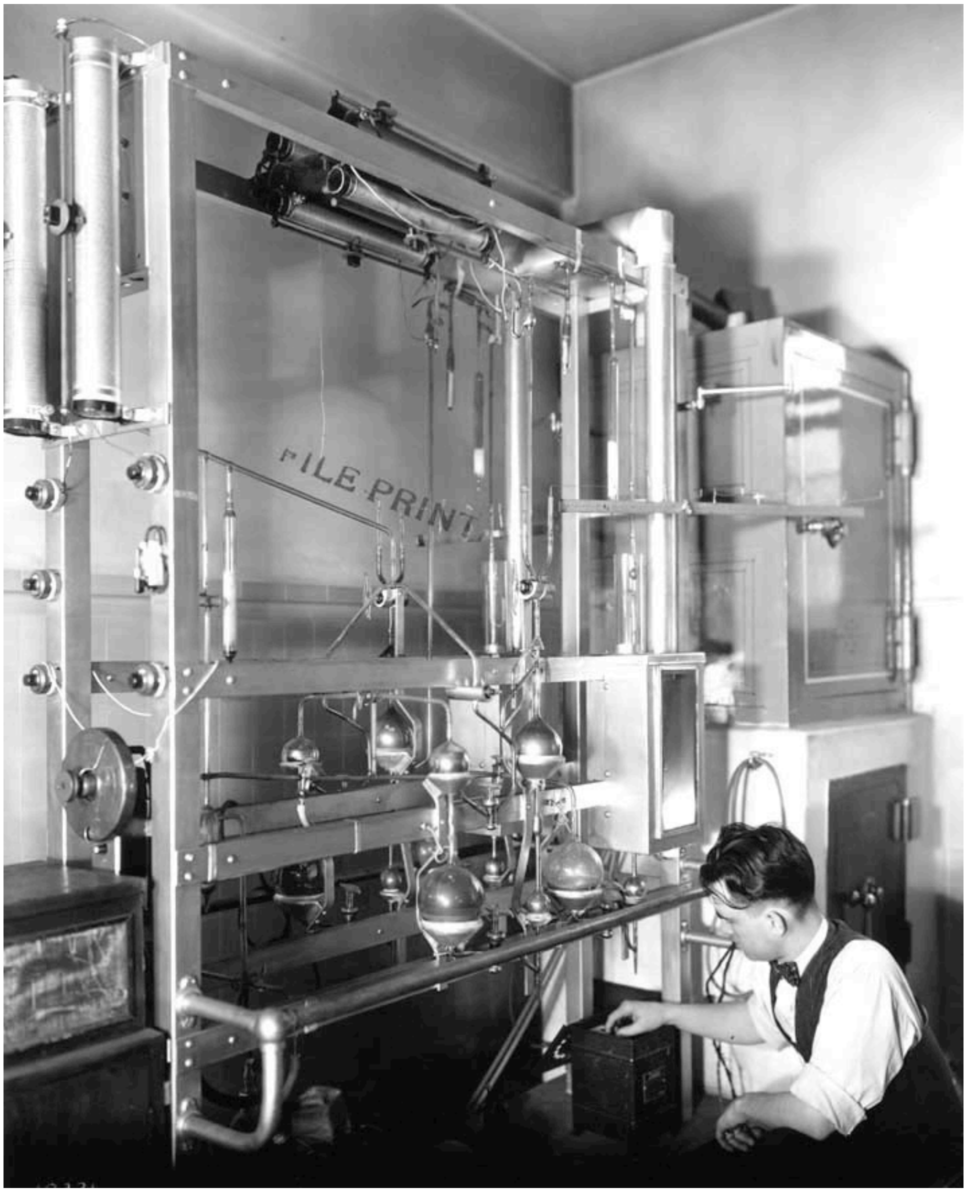

Figure 4.3. The radium emanation plant of the University of Minnesota Cancer Institute in 1930. The design is largely unchanged from Duane's. The safe containing the radium is on the right. Photo courtesy of the University Archives, University of Minnesota, Twin Cities.

Within a few years, Duane and the Huntington Hospital were treating over 500 patients each year with emanation from his plant.[378] As radium therapists learned of the benefits of Duane's plant, many of those with the resources began to work to install plants of their own. By 1919, in addition to the Huntington, the Kelly clinic, Memorial

[378] Brucer, "William Duane and the Radium Cow," 1603.

Hospital, the Simpson Radium Institute in Chicago, and the Mayo Clinic were using radium emanation plants.[379] Duane went to Memorial in 1915 to install their plant.[380]

The development of radium emanation plants and the acceptance of the superiority of emanation over radium for many therapies established hospitals as the appropriate sites of radium therapy. Only hospitals, or large, dedicated radium therapy clinics like Kelly's and Simpson's, could afford to purchase, maintain, and staff an emanation plant. Emanation plants required a minimum of half a gram of radium, which if purchased in the 1910's could cost between $30,000 and $90,000, and this cost alone put the apparatus out of reach of general practitioners.[381] Standard Chemical's lead physicist, Charles Viol, realized this, writing in 1921: "a demand for radium emanation will force the physicians to coöperate to pool their supplies for the more economical production of radium emanation."[382]

Needing the full-time services of a staff physicist, in 1915, Memorial Hospital hired Gioacchino Failla. He had earned a degree in electrical engineering from Columbia

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379 Charles H. Viol, "Description of an Apparatus for the Collection, Purification and Tubing of Radium Emanation from a Radium Solution," *Radium* 14 No. 1 (October, 1919): 2.

380 Webster, "The Origins of Medical Physics in the USA," 1610.

381 Lubenau and Mould, "The Vanadium Window:" 192e. Converting 1915 dollars to today's money, this would represent around $700,000–$2 million; in 1919, a half gram of radium would could around $400,000–$1.2 million in today's dollars. The Inflation Calculator, http://www.westegg.com/inflation. It is worth noting that some hospitals, like the Kelly Clinic or Memorial Hospital, could rely on stores of medical radium accumulated over many years; many others that were new to radium therapy, like the University of Minnesota's Cancer Institute, were able to enter the field because of philanthropic gifts. Of the original gift of over $250,000 that established the Cancer Institute, $50,000 was set aside for the purchase of an X-ray machine and a half-gram of radium. For more, see Aimee Slaughter and John Kersey, "Philanthropy and Scientific Medicine: The Cancer Institute at the University of Minnesota," *Minnesota Medicine* (September, 2011): 47–49.

382 Charles H. Viol, "History and Development of Radium-Therapy," *Journal of Radiology* 2 (1921): 33.

University that year, and two years later received his MA in physics. In 1923, he was awarded his physics PhD from the Sorbonne, under the direction of Marie Curie, physicist Jean Perrin, and chemist André-Louis Debierne.[383] One of the most important contributions Failla made to radium therapy was the introduction of gold radium seeds, which Memorial began to use in 1926. Glass "seeds" of radium were implanted into tumors, but soft beta rays were not absorbed by the glass and caused unwanted damage to nearby healthy tissues.[384] This problem was pointed out by Paris radium therapist Claudius Regaud, and, after experimentation, Failla proposed the solution of replacing the glass seeds with gold seeds. The gold would absorb the soft betas, allowing only the therapeutically useful hard betas and gammas to escape into the patient's body.[385] Failla also studied Duane's emanation plant and made some improvements of his own. Both Duane and Failla traveled to clinics throughout the country to help with the installation of emanation plants.[386]

After returning from military service in World War I, Failla was "in search of an assistant" and hired Edith Quimby in 1919, who had earned her master's in physics from

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[383] Debierne had been a close associate of Curie for many years, and Perrin was one of the leading physicists in France.

[384] A ray is labelled as soft if it is easily absorbed. Soft betas therefore traveled a short distance before being absorbed, and if they were left unfiltered the tissues surrounding the seed would receive disproportionately large amounts of energy. Gammas and hard betas were preferred for therapy because they are higher-energy and travel farther, and so would deliver large amounts of energy to the targeted tumors without burning or overexposing the skin or other interposed healthy tissues in the process.

[385] For more, see Jesse N. Aronowitz, "Buried Emanation: The Development of Seeds for Permanent Implantation," *Brachytherapy* 1 (2002):167–178.

[386] Failla installed the emanation plant in Standard Chemical's Radium Research Laboratory; ibid.: 2.

the University of California-Berkeley three years earlier.[387] Working together, Failla and Quimby undertook groundbreaking research in radium therapy, especially in precisely calibrated individual dosage plans.[388] One of her innovations was the introduction of the threshold erythema dose. Radium therapists, and X-ray therapists, had long used the reddening of a patient's skin, called an erythema reaction, as a guide for how long treatment ought to last. However, this reaction was highly dependent upon an individual patient's case and skin; one patient might show erythema after the absorption of low amounts of energy, while another might receive serious injury before the skin began to redden. By defining this dose as the amount of radiation that would cause a discoloration of the skin in 80% of patients two to four weeks after radiation, Quimby was able to attach an energy value to the concept of erythema, making it a quantitative measurement of dosage equally applicable for all patients.[389] For treatments involving implantation of radium or radon needles or seeds, she defined an "erythema" dose based on complex calculations.[390] In experimentally determining these doses, Quimby used materials like butter and water phantoms as models for the human body.[391] Her calculations from these

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[387] Edith H. Quimby, "The Clinical Radiation Physicist—A Specialist within the Field of Radiology," *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 72 (1954): 733. Quimby had moved to New York City because her husband took a job there.

[388] Failla tended to be responsible for the instrumental and engineering problems, and Quimby for the mathematical and more patient-related problems, though there was considerable overlap in these areas. Harold H. Rossi, "Edith Hinkley Quimby," *Physics Today* (December 1982): 71.

[389] George T. Pack, "The Principles Governing the Radiation Therapy of Cancer: An Elementary Lecture," *American Journal of Roentgenology and Radium Therapy* 36 (1936): 234–235.

[390] In this dosage, erythema is in quotes because it is not based on actual reddening of the patient's skin, rather on her calculations based on tissue absorption. Edith H. Quimby, "Determination of Dosage for Long Radium or Radon Needles," *American Journal of Roentgenology and Radium Therapy* 31 (1934): 74–91.

[391] Butter is mentioned in ibid. A water phantom is a container of water used to represent the body.

models resulted in equations and tables, published with her research in medical journals, which physicians used to determine safe and effective doses. Over the course of her career at Memorial, Quimby also taught over a thousand physicians about radiation therapy.[392]

> In 1954, Quimby lists the tasks of a hospital physicist in the following categories:
>
> Calibrations ... Roentgen-ray dose planning ... Radium dose planning ... Radioisotope calibration, dispensing, and measurements ... Radiation protection ... Resident training ... Research[393]

Radioisotopes did not become an established hospital therapy until after the end of World War II, but the rest of these categories are relevant in the period we are currently considering. Quimby goes on in her 1954 address to emphasize:

> This man or woman is not a technician, nor even a supertechnician; but a professional person, and should be treated as such. ... He has no desire to supersede the radiologist, or to take over the treatment of patients, but he does want a defined position within the field of his choice.[394]

Radium therapists realized the necessity of having a physicist on staff, and these physicists were never mere technicians; but their professional status was unsettled in the 1920s and 1930s (and even into the 1950s, as Quimby's words demonstrate). When the American Radium Society was founded in 1916, physicists could be associate members only. The second physicist to join, after Standard Chemical's Charles Viol, who was a

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[392] Rossi, "Edith Hinkley Quimby," 71. After the introduction of radioactive isotopes into medicine, Quimby continued to work with these new sources of radioactivity. Ibid.: 72.

[393] Quimby, "The Clinical Radiation Physicist," 734–5.

[394] Ibid., 736.

founding member, was Failla, who was invited to join in 1918. According to Quimby, the next physicists to join were herself and Stenstrom, in 1925.[395]

Looking at the Kelly Clinic can show us how radium therapists relied on physicists before and after the adoption of radium emanation plants. In 1910 or 1911, soon after the establishment of the curie, Howard Kelly sent 100 mg. of radium he had recently acquired to Yale radiochemist Bertram Boltwood for verification of its strength. Boltwood was the leading American expert on radioactivity. Boltwood's own radium had been gamma-calibrated to the standard sample in Vienna, and so could provide a measurement of the strength of Kelly's sample with great certainty. When he found that Kelly had been sold 40 mg. less than he had paid for, Kelly was able to ask for and receive the missing amount on Boltwood's authority.[396] Kelly relied on Boltwood's expertise and authority on a few occasions, and borrowing from the authority of scientists was one important aspect of the interactions between physicians and scientists in radium therapy.[397] Learning from this experience, when Kelly sent his associate Curtis Burnam to buy radium from Stefan Meyer, director of the Vienna Institute for Radium Research

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395 Ibid., 734. Quimby mistakenly states that "No physicist was a charter member," a misstatement that is perhaps indicative of the fringe status of commercial physicists in hindsight. The ARS opened full membership to physicists in 1951; in 1956 Quimby stated there were 15 non-physician members of the around 300 total members. Quimby, "The Background of Radium Therapy in the United States, 1906–1956," 445.

396 Burnam, "Early Experiences with Radium," *American Journal of Roentgenology and Radium Therapy*: 438. Pioneering radium therapist Robert Abbe similarly had his radium preparations measured by Columbia physicist George Pegram (who during World War II was instrumental in allowing Enrico Fermi to escape to America, and in the work of the Manhattan Project). Congress, House of Representatives, Committee on Mines and Mining, *Radium: Hearing Before the Committee on Mines and Mining of the House of Representatives on H. J. Res. 185 and 186*, 63rd Cong., 2nd sess., January 19–28, 1914, 350.

397 Vivien Hamilton has worked on the rhetorical uses of this borrowing of authority from science and scienists in radiation therapy; for example, "X-Ray Safety," talk at 2012 History of Science Society / Philosophy of Science Association meeting in San Diego, California, November 15–18, 2012.

and one of the leading physicists researching radioactivity, he directed Burnam to bring the radium to the London Radium Institute for verification, against their standard, of Meyer's measurements. By 1913, Burnam reported that they were confirming the strength of their domestically-purchased radium against their own standard.[398]

Boltwood traveled to Baltimore in 1911 to install a small emanation plant, using only 30 milligrams of Kelly's radium.[399] This plant relied on liquid air to freeze the emanation and thereby separate it from the other gases present: a more cumbersome setup than the pumps involved in Duane's later apparatus.[400] The Kelly Clinic later transitioned to Duane's more elegant and practical emanation plant.

In the early 1910's, Kelly determined that he needed to hire a full-time physicist to manage his radium supply and all of the related equipment. In 1912, he traveled to Europe and met with many scientists, including Ernest Rutherford and Frederick Soddy; at Rutherford's suggestion he hired one of his assistants at the University of Manchester, physicist Walter Lantsberry. Rutherford told Kelly that "physicians working with radioactivity must have a physicist."[401] Before arriving in Baltimore, Lantsberry wrote to Kelly asking if he had any standardized radium samples, and requested that Kelly send

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398 Burnam brought a letter of introduction from Boltwood to Meyer, and to Ernest Rutherford at the University of Manchester. He carried the radium purchased in Vienna "in my overcoat pocket until I was safely on the train" and before he reached London his skin was burned and he was nauseated from the effects of the radium upon his liver. Burnam, "Early Experiences with Radium," 447, 448.

399 Burnam, "Early Experiences with Radium," 438.

400 Quimby, "The Background of Radium Therapy in the United States, 1906–1956," *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine*: 444.

401 Kelly's recollection of Rutherford's words, as recorded in his diary of February 11 to April 14, 1914. Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes, Box 25, Folder 6. See also Burnam's recollection of this decision in Burnam, "Early Experiences with Radium," 450.

him several of his radium tubes so that he could measure them against Rutherford's standard, and create a standard if Kelly did not already have one.[402] After his arrival, Lantsberry designed and installed an emanation plant in Kelly's clinic, which was then managed by another associate of Rutherford's, his student Fred West, whom Kelly also hired.[403] (This plant was a much improved model compared to the one Boltwood had installed in 1911.) West stayed with the Kelly Clinic for many years, working with Kelly and Burnam.

In 1921, Charles Viol estimated that there were 35–40 grams of medical radium in use in the United States. He counted two institutions, unnamed but certainly the Kelly Clinic and Memorial Hospital, that had more than four grams of radium; only four more with more than a gram; and seven with more than a half gram.[404] So at the beginning of the 1920's there were perhaps 13 institutions that could support an emanation plant. "Within the next three years [after I was hired in 1919]," Quimby later wrote, "[Karl Wilhelm] Stenstrom at the New York State Institute for the Study of Malignant Disease, [James Lloyd] Weatherwax at Philadelphia General Hospital, and [Otto] Glasser, with [Hugo] Fricke, at the Cleveland Clinic, began the development of radiation physics departments."[405] This list is by no means exhaustive—it leaves out the two physicists

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[402] Letter of March 30, 1914, Box 7, Radium Correspondence—1914–1915 folder, Howard A. Kelly Collection, Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutes.

[403] Edward R. Landa, *Buried Treasure to Buried Waste*, 60. Later, Kelly was able to repay the favors to Rutherford: at James Chadwick's request, the Kelly Clinic sent him old radon seeds for experimentation, useless for therapy but which were a valuable source of polonium. These were an important part of Chadwick's research that led to the discovery of the neutron. 60–61.

[404] Viol, "History and Development of Radium-Therapy," 33–34. The weight of radium given is presumably the weight of radium element present in the salts; Viol preferred this unit, because it measures the activity of the radium salts rather than their weight.

[405] Quimby, "The Clinical Radiation Physicist," 733.

who Kelly hired to work at his clinic—but these are some of the major pioneers in the physics of radium therapy.[406] The leading physicists that Quimby listed all held physics Ph.D.s and had impressive experience: Glasser worked briefly at the Kelly Clinic, Weatherwax studied with physicist Karl Compton (brother of Arthur Compton), Fricke spent two years working with Niels Bohr, and Stenstrom worked for a year each with William Duane and Robert Millikan.[407]

In 1932, the Bureau of Mines sent out a survey to hospitals and physicians about their use of radium. An overview of their statewide results is given in Fig. 4.4 and Table 4.1, as maps and tables of the top ten states owning radium overall and per capita. The five states that had the most radium overall—New York, Illinois, Pennsylvania, Massachusetts, and Maryland—also appear in the top ten states per capita; outside those top five, Minnesota also appears in the top ten states on both lists.[408] Major hospitals in New York City, Chicago, Philadelphia, and Boston account for their states' high placement in both lists, and Kelly's clinic in Baltimore made Maryland the state with the highest amount of medical radium available per capita. Two hundred and eighty-seven

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[406] As another example, dermatologist Frank Simpson had hired two physicists by 1922: first was Miss A. B. Hepburn, who was replaced by Mr. Melvin Mooney. It is unknown what sort of training they had, but it is apparent that neither had a Ph.D. when hired. Simpson, *Radium Therapy*: i.

[407] For more on each of these men, see: Marvin M. D. Williams, "Otto Glasser (1895–1964)," *Radiation Research* 31 (1967): 180–182; Leonard Stanton, "James L. Weatherwax: Pioneer in the Physics of Radiology," *RadioGraphics* 6 (1986): 331–335; Edwin J. Hart, "Hugo Fricke, 1892–1972," *Radiation Research* 52 (1972): 642–646; Loken, "Karl Wilhelm Stenstrom, Ph.D.," *American Roentgen Ray Society*: 472–474.

[408] R. R. Sayers, *Radium in Medical Usage in the United States*, U.S. Bureau of Mines Information Circular 6667 (1932). Washington, D.C. is not represented in the maps; it was reported to have 650.5 mg of medical radium.

hospitals and clinics, 414 physicians, and 9 laboratories and companies responded to the survey reporting that they used radium.[409]

[409] Overall, the survey had an 83% response rate from hospitals and clinics. Ibid., 5–6.

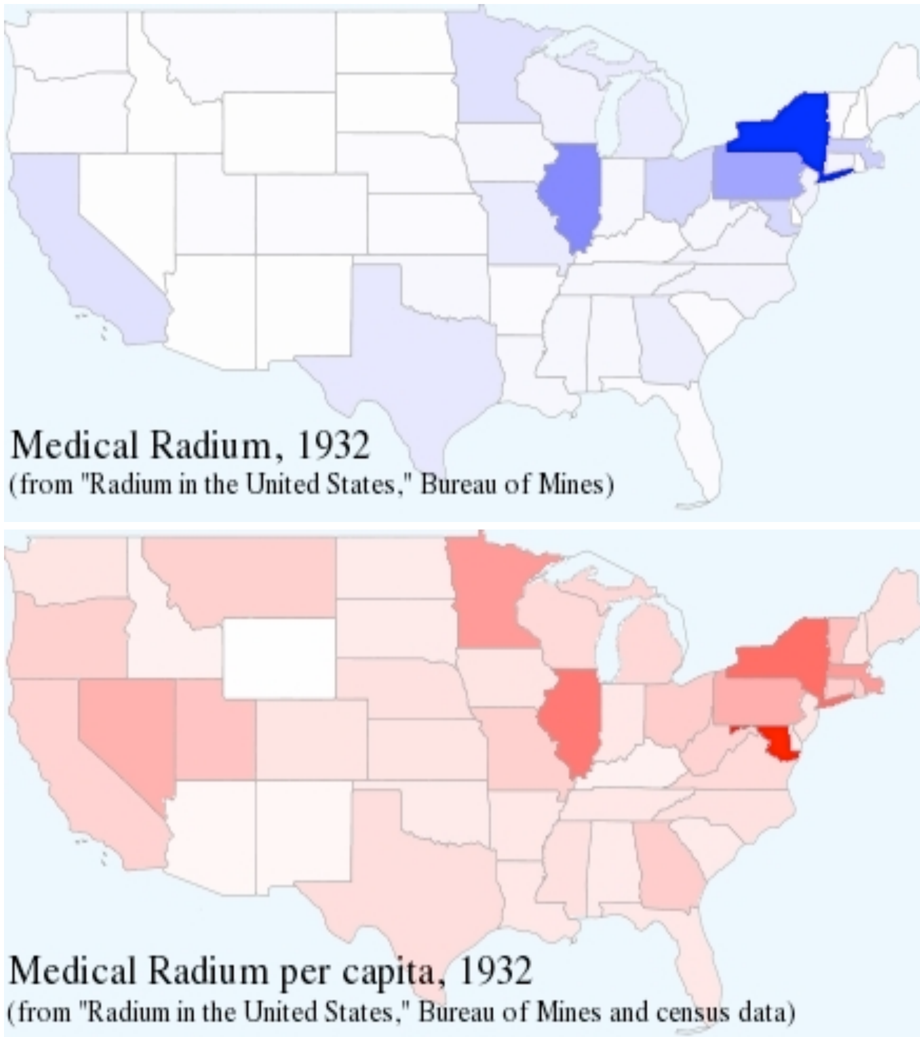

Figure 4.4. Maps showing the distribution of medical radium in 1932, based on data from Sayers, Radium in Medical Usage in the United States *and census data.*

State	Medical Ra (mg)	State	Mg Ra per Ten Thousand People
New York	29,800.61	Maryland	34.54
Illinois	16,544.82	D.C.	26.55
Pennsylvania	12,952.21	New York	22.92
Massachusetts	6,994.96	Illinois	21.39
Maryland	5,795.00	Massachusetts	16.42
Ohio	5,716.07	Minnesota	16.25
Minnesota	4,299.00	Pennsylvania	13.27
California	4,256.11	Nevada	12.76
Texas	3,313.49	Vermont	10.42
Michigan	3,120.26	Utah	9.77

Table 4.1. Tables showing the distribution of medical radium in 1932, based on data from Sayers, Radium in Medical Usage in the United States *and census data.*

The situation at the beginning of the 1930s was thus very different from that ten years earlier. Around 40% of the 287 responding physicians and hospitals that had radium had 0.75 grams or more, enough to run an emanation plant.[410] Wyoming was the only state that reported having no medical radium. As shown in Fig. 4.5, the medical radium in use was mostly in needles for surgical insertion, but this was not much more than that used in tubes for external application or in solution for an emanation plant.[411] The 24% in solution, and therefore in use in emanation plants, shows the growing transition to emanation therapy—and the growing presence of physicists in hospitals to manage these plants and collaborate on therapy. This was the turning point for radium emanation therapy—leading radium therapy hospitals had installed emanation plants and other hospitals were beginning to follow suit.

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[410] 44.6% of hospitals, 41.3% of physicians, and 55.6% of labs and companies that owned radium owned at least 0.75 grams. Ibid., 5.

[411] Not all of the respondents reported how they used their medical radium; the 107.81 grams of radium represented in the chart above account for about 86.5% of the medical radium reported. Ibid. The survey respondents reported around 124.63 grams of radium; however, "The total production and imports into this country to the end of 1930 have been in the neighborhood of 288.4 grams. It is probable that since 1916, including use during the Great War, not more than an average of 2 grams per year has been used in luminous materials, a total of not more than 30 grams ... [exports] have probably not exceeded 20 grams ... so that, making no allowances for broken tubes and other losses there would appear to be still in this country 238 grams of radium. This is very much more than can be accounted for from holdings." Ibid., 4.

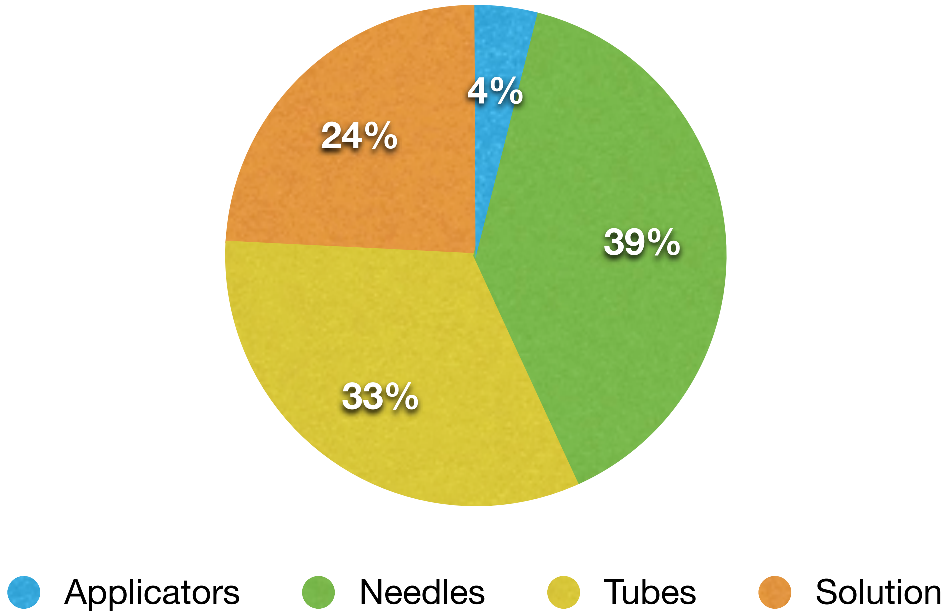

Figure 4.5. Usage of 107.81 g of radium as reported in Sayers, Radium in Medical Usage in the United States. *The radium in solution represents the radium used in emanation plants.*

The growing importance of radium emanation plants for medicine is also indicated by the fact that overall the 710 respondents, who in total owned about 124.7 grams of radium, desired 117.4 grams more: in other words, the community of American radium therapists wanted around 94% more radium than they owned.[412] This perceived need to almost double the amount of available medical radium was due in large part to the minimum of 500 milligrams of radium needed to maintain a cost-effective radium emanation plant.

Realization of Dangers and Changes at the End of the Professionalizing Period

The short-term, superficial negative effects of radium had been known since its first therapeutic use in 1901—its ability to burn the skin first inspired clinical

412 Ibid., 5.

experimentation with the new element. In this professionalizing period, physicians also discovered that detrimental effects could also be produced by prolonged exposure to radioactivity. As a result, physicians began to implement safety measures to protect themselves, their staff, and their patients against these chronic symptoms. It took the deaths of workers in a radium paint factory and a well-known socialite who drank commercial radium tonics towards the end of this period for it to become apparent that radium, when taken into the body, did not completely leave the body within a matter of days, as internal radium therapists had maintained for years—rather, it became fixed to the bones as a continual source of radioactivity. As this section will detail, the deaths that resulted from these tragedies led to the end of internal radium therapy, which had become increasingly a fringe therapy in the preceding years. External radium therapy, in contrast, had found a stable home in hospitals and continued to prove its usefulness. The end of this period is marked by physics discoveries that led to radium therapy's replacement, in the years after the end of World War II, by the medical use of radioactive isotopes.

The dangers of radium were not well understood for many years. It was very quickly established that radium produced burns on the skin, and that severe burns were often accompanied by nausea—but unlike the burns from X-rays, radium burns healed quickly and extended exposures did not appear to set up the progressive illness that claimed the lives of many X-ray pioneers.[413] By the early 1920s, however, it became clear that prolonged exposure to radium would decrease the red blood cell count and

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[413] Many X-ray workers developed cancers in their fingers, and often would begin a series of successive amputations in an attempt to stem the progress of the disease. For more on the deaths of roentgenologists and how these deaths were understood by the community, see Rebecca Herzig, "In the Name of Science: Suffering, Sacrifice, and the Formation of American Roentgenology," *American Quarterly* 53 (2001): 563–589.

eventually cause anemia. This led radium clinics to introduce better shielding of their radium, when in therapeutic use and not, to protect the health of their providers and patients.

One of the first articles drawing the profession's attention to the chronic dangers of overexposure to radium was published in *JAMA* in 1916.[414] Radium therapist Thomas Ordway presented nine case histories of physicians, nurses, and medical students who suffered from pain and loss of sensation, loss of dexterity, and sometimes increased awareness of heat or pressure in their hands. These effects were "in spite of caution" because "injurious local effects were anticipated," and precautions were taken against short-term effects.[415] To protect against the long-term effects he observed, Ordway suggested the use of forceps in handling radium, to maintain distance between the salts and the hands, and the implementation of staff rotation to ensure that no one person received daily exposure for an extended period of time. These recommendations were slowly adopted by radium therapists. Howard Kelly outlined the detailed safety measures in place in his hospital in 1922 in *The Modern Hospital*.[416] By that time, it was understood that anemia could result from prolonged over-exposure to radium (in addition

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[414] Thomas Ordway, "Occupational Injuries Due to Radium: Report of Cases," *JAMA* 66 (1916): 1–6.

[415] Ibid., 1.

[416] Howard A. Kelly, "The Care of Radium in the Hospital," *Radium* 1 No. 9 (September, 1922): 291-294. Abstracted from *The Modern Hospital* 18 No. 5 (May, 1922).

to the pain described by Ordway).[417] At the Kelly Clinic, personnel were rotated through radium handling duties, strict guidelines were in place regarding shielding and the use of forceps, and fans were continually running in rooms where radium was stored to circulate out any emanation that might escape into the room. To ensure the safety of the nurses, who prepared all of the applicators, nurses worked with the radium only for six weeks, and afterwards their blood was checked and they were given two weeks off. Additionally, there was a "head radium nurse" who "remains permanently on duty but never gives treatments." This head radium nurse instructed the other nurses in proper handling and application of radium and ensured that the safety rules were being followed.[418] The doctors', physicists', and technicians' blood was regularly checked every month. The practices in the Kelly Clinic were fairly standard for radium clinics

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[417] Kelly spoke of the risk of "a profound rebellious anemia" as an accepted fact (not as a new discovery) in his 1922 report. Kelly, "The Care of Radium in the Hospital," 292. In 1922, a report appeared in the *Journal of Experimental Medicine* on animal studies investigating the possibility of using germanium dioxide in treating radium-induced anemia, and was abstracted in *Radium*. Frederick S. Hammet, Joseph E. Nowrey, and John H. Muller, "The Erythropoietic Action of Germanium Dioxide," *Radium* 1 (1922).
Ironically, at some point in the 1910s, the SCC ran a radium clinic aimed specifically at treating anemia. Congress, Senate, *Minerals and Metals for War Purposes: Hearings Before the Committee on Mines and Ming of the Senate on the Bill H.R. 11259,* 65th Cong., 2nd sess, May 2–29, 1918: 405. Among those reported to have died of anemia caused by overexposure to radium are leading French therapist Henri Dominici, American therapist Sanford Withers, 5 unnamed workers at the Radium Institute of London, and Marie Curie. Harrison S. Martland, Philip Conlon, and Joseph P. Knef, "Some Unrecognized Dangers in the Use and Handling of Radioactive Substances," *JAMA* 85 (1925): 1774. W. W. Wasson, "In Memoriam: Sanford Withers, M.D.," *Radiology* (May, 1938): 651. George E. Pfahler, "The Effects of the X-Rays and Radium on the Blood and General Health of Radiologists," *American Journal of Roentgenology* 9 (1922): 647–656.

[418] Kelly, "The Care of Radium in the Hospital," 293. Kelly notes that the "instructress" was "a woman of high intelligence."

and hospitals, as the importance of staff rotation, regular blood checks, and lead shielding and distance were well understood in the mid-1920s.[419]

Patients were of course also in danger of overexposure to radium. When the safety of patients is a consideration, so are the possible legal implications of accidental harm. These "medicolegal" implications were considered in a few places in the literature by radium therapists. Joseph Bissell, surgical director of the Radium Sanatorium of New York, published on these implications in 1917. Bissell considered radium therapy to be, on the whole, a safe treatment. Echoing the sentiments of many at the beginning of the century, he wrote that "experience has shown that radium is accepted as harmoniously in the body as is sunlight by the withering plant."[420] Bissell was a proponent of internal radium therapy, and considered it as proven that ingested or injected radium swiftly left the body. With "few opportunities for mistakes" in radium therapy, he concluded that "the time will soon be at hand when the practitioner who does not use all methods of treatment at hand [including internal radium therapy] ... will be guilty of malpractice and so charged."[421]

The dangers being considered so far were all short-term effects of radium therapy: no long-term effects had yet been observed. This changed with the very public suffering of the "radium girls"—women who worked as watch dial painters who, years after

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419 In addition to Kelly's and Ordway's reports, see, for example, Pfahler, "The Effects of the X-Rays and Radium on the Blood and General Health of Radiologists" and R. C. Williams, "Preliminary Note on Observations Made on Physical Condition of Persons Engaged in Measuring Radium Preparations," *Public Health Reports* 38 (1923): 3007–3028.

420 Joseph B. Bissell, "The Medicolegal Aspects of Radium-Therapy," *Medical Record* (July 21, 1917): 102–104, reprinted in *Radium* 9 No. 6 (September, 1917): 97–101.

421 Ibid., 101.

ingesting radium paint daily when they brought their brushes to a point in their mouths, began to develop serious health problems, especially in their jaws. Their illness began to become apparent in 1922, and they brought suit agains their employer five years later.[422] The 1932 death of socialite Eben Byers drove home the dangers of radium, and internal radium therapy in particular.[423] His daily intake of a commercial radium water led to the slow destruction of his body, and his death was greatly publicized. That year, the American Medical Association removed internal administration of radium from its list of New and Nonofficial Remedies, which placed internal radium therapy beyond the pale of accepted medical practice.[424] These tragedies involved the ingestion of radium; hospital-based radium therapy was firmly devoted to external radium therapy by that time and was

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[422] Their story and its implications are studied in Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910–1935* (Chapel Hill: University of North Carolina Press, 1997). After radium poisoning began to be identified, some patients were treated for this poisoning, as described by Robley Evans in a series of interviews with the American Institute of Physics: Interview of Robley Evans by Charles Weiner, May 2, 1972–June 14, 1978, Niels Bohr Library & Archives, American Institute of Physics, College Park, MD USA, www.aip.org/history/ohilist/4594_1.html.

[423] His body was studied in 1933 and again in 1965, and measurements showed that he carried 6.1 μCi in his body, indicating he had probably drunk more than 1,400 bottles of Radithor. R. E. Rowland, *Radium in Humans: A Review of U.S. Studies* (Argonne, Illinois: Argonne National Laboratory, 1994). http://www.osti.gov/cgi-bin/rd_accomplishments/display_biblio.cgi?id=ACC0029&numPages=246&fp=N

[424] A brief discussion of the medical community's realization of the long-term dangers of internal radium therapy, and a medical study of several patients who had received this therapy, can be found in Looney, Hasterlik, Brues, and Skirmont, "A Clinical Investigation of the Chronic Effects of Radium Salts Administered Therapeutically (1915–1931)." However, the Belgian company producing the majority of the world's medical radium was still endorsing internal radium therapy in 1932. *Radium: Production, General Properties, Therapeutic Applications, Apparatus* (Brussels: Union Minière du Haut Katanga, Radium Department, 1932): 190.

little affected by the publicity.[425] Additionally, radium therapists, and hospital physicists, had established radium therapy as a profession within medicine, distancing themselves and their practices from commercial radium products.

Change was on the horizon for radium therapy, however. 1932 is known as "the miracle year" in nuclear physics—and the monumental discoveries of that year had implications for radiation therapy.[426] James Chadwick famously discovered the neutron that year, and Ernest Lawrence developed the cyclotron. Two years later, Irène and Frédéric Joliot-Curie discovered the phenomenon of artificial radioactivity. This discovery gave cyclotrons new meaning: they could now be used to create radioactive isotopes. Identical to their non-radioactive counterparts, except for the number of their neutrons, radioactive isotopes could be used to target specific organs because the body's chemical pathways would make no distinction between the endogenous non-radioactive isotope and the exogenous radioactive isotope.[427] Though artificial radioisotopes dramatically changed the possibilities of radiation therapy, radium emanation continued to be used in hospitals well into the 1950s and in some cases beyond.

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[425] Looking back in 1954, a scientist with the U.S. Naval Hospital's Radioisotope Laboratory stated that internal radium therapy was on the decline by 1930. William B. Looney, "The Initial Medical and Industrial Use of Radioactive Materials (1915–1940)," *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 72 (1954): 839. Also, one of the most prominent supporters of internal radium therapy, C. Everett Field, ended his internal radium therapy practice in the late 1920's. R.E. Rowland, *Radium in Humans*: 5.

[426] For more on the importance of this year to nuclear physics, see, for example, Roger H. Stuewer, "The Nuclear Electron Hypothesis" in *Otto Hahn and the Rise of Nuclear Physics*, William R. Shea, ed. (Dordrecht: D. Reidel, 1983): 19–67 and Brian Cathcart, *The Fly in the Cathedral: How a Group of Cambridge Scientists Won the International Race to Split the Atom* (London: Viking Penguin, 2005).

[427] Radioactive iodine, for example, was—and still is—used to target the thyroid, which uptakes iodine. Radioisotope therapy has been studied by Angela Creager, for example, "Nuclear Energy in the Service of Biomedicine: The U.S. Atomic Energy Commission's Radioisotope Program, 1946–1950," *Journal of the History of Biology* 39 (2006): 649–684.

American radium therapy was able to establish itself as a hospital-based therapy in this professionalizing period because of the increasing importance of physical knowledge and physicists. By the 1910s, significant numbers of physicians attested to the efficacy of radium therapy, and was seriously considered as something the government might protect in the halls of Congress. We have seen how the establishment of the curie and the adaptation of the radium emanation plant from the physics laboratory to the clinic revolutionized the precision and the breadth of radium therapy. The physicists who were hired by the first hospitals that installed emanation plants were highly skilled and many had trained with leading European physicists. In their work as hospital physicists, these men and women were not technicians, but integral parts of a medical team that determined treatment plans based on clinical experience and laboratory calculations. Radium therapy's move from private practices to large hospitals, characteristic of this professionalizing period, was made possible by collaboration with physicists.

Conclusion

Physicists, Physicians, and Physical Therapy

The Character of Early American Radium Therapy

Physicians and physicists worked side-by-side in hospital radium therapy clinics in the 1920s and 1930s. In earlier decades, although they did not share workspaces in the same way, physicians and physicists still collaborated: discoveries made in physics laboratories shaped clinical decisions, and connections with networks of radioactivity researchers allowed physicians to acquire radium salts. Through practical, educational, and rhetorical influences, physics fostered and bounded the development of American radium therapy.

This study has identified two distinct periods in early American radium therapy: an experimental period, 1900–1910, and a professionalizing period, from 1911 to around 1934. The turning point between these two periods was the establishment of an American radium industry, which dominated the global market for a decade, and a Congressional debate over nationalizing American radium ores to conserve the country's supply of medical radium. These were hallmarks of American radium therapy beginning to establish itself as a respected therapy, especially in the treatment of cancer.

The first period is characterized by the radium craze of 1903–1907, a time when the American public took an enormous interest in the newly-discovered element and speculated on its potential uses. These included medical applications, and physicians were already using radium in the experimental treatment of a wide variety of maladies by interested physicians. Many of these physicians had an interest in science or experience with other physical therapies like roentgenology or electrotherapy. Radium salts were not easily acquired on the market, especially after the radium craze increased the demand for an already scarce substance, and the medical community was generally skeptical of the over-publicized new therapy. Interested physicians tapped into networks of physicists to borrow some of their radium or to gain access to importers of radium, which was exclusively produced in France and Germany. After acquiring some radium, a basic understanding of the physics of radioactivity provided these early adopters with a framework for beginning their new therapy. The medical literature had little that was certain to say about radium therapy, so physical discoveries provided an accepted groundwork. Knowledge of the basic differences between alpha, beta, and gamma rays led physicians to filter their radium to select the rays they found to be most clinically efficacious.

The second period of American radium therapy saw several important changes in the ways physicians and physicists interacted. Radium therapists placed greater importance on physics knowledge, and made this knowledge part of their professional identity. Their improved understanding of the physics of radioactivity led to changes in methodology. Additionally, the introduction of the clinical radium emanation plant by a physicist opened a new avenue of therapy, one which allowed greater flexibility in dosage but required large amounts of radium. Radium therapy became a hospital-based therapy, and was overseen by physicists, part of hospital staffs for the first time.

The changes in American radium therapy across these two periods demonstrate the crucial roles physics played in its development. An understanding of filtration gave physicians boundaries for their dosage decisions, and across the decades physicists provided medical radium sources and consulted with physicians on treatment decisions. Effective, safe radium therapy came to mean a therapy based on the basic science of radioactivity, and professional radium therapists were physicians worked side-by-side with hospital physicists.

Throughlines of This Study

There are several larger themes that run throughout the history of early radium therapy. The new element's popularity influenced physicians and patients as well as the general public. Across the two periods of early American radium therapy, we can track changes in how radium therapists understood the physics of radioactivity, and in how they interacted with physicists and physics networks. Finally, there is the development of a professional identity by radium therapists, and the role physics played in that development. In this section we will consider these four themes in turn to gain a broader perspective of them and the changes that occurred in radium therapy in the first decades of the twentieth century.

The radium craze was a sharp spike in popular interest in radium, which remained a popular subject even after the craze subsided around 1907. The publicity around radium made it familiar, as a concept if not as a physical object, to the American public. The media reported on radium's uses, potential and actual, which added to the popular understanding of it and inspired further medical investigation. In 1925, radium therapist

C. Everett Field summarized the effects he saw the popularity of radium have on his field:

> The pendulum of popular interest and acceptance [of radium therapy] swung high in its favor in 1907 and 1908, only to drop back into failure in as short a time. Probably the real case for the disappointment was due to the fact that the radium of that day was very impure salt [sic] ... The second popular acceptance of radium during the periods of 1911 to 1914 resulted in over-enthusiastic claims by those who were sponsoring its use and again with the advent of the Great War it lost its hold and classed in some disfavor. Since 1918 there has been a steady increase in acceptance as a major remedy for cancer and without any special publicity it has grown to be an agent of tremendous prestige.[428]

The "over-enthusiastic claims" did not endear radium therapy to the general medical community, already inclined to skepticism because of the hyperbolic reports of the press. Though the popularity of radium led some individual physicians to investigate is therapeutic uses, it also set a high bar for radium therapy to meet for it to gain the acceptance of the wider medical community.

The physics of radioactivity was relevant to radium therapists over both of the periods studied here, but how they understood and applied physics changed over time. In the experimental period, physics was not consistently related to clinical concerns. The existence of three different kinds of rays emitted by radium was, for example, consistently presented in texts from this period, but how this information was translated into clinical decisions was dependent upon the skills and interest of individual physicians. Even when a conclusion based on physics knowledge, like the necessity of filtration for safe dosage, was agreed upon in the literature, there was no consensus about the specifics of filtration or dosage. In the second period, physics knowledge was directly related to

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[428] C. Everett Field, "Radium: Yesterday and Today," *Medical Life* (October 1925): 358.

clinical concerns in radium therapy books. Furthermore, experienced radium therapists insisted that scientific expertise, and reliance on help from physicists, be a required part of acceptance as a radium therapist as they started to professionalize.

How radium therapists interacted with physicists also changed over the two periods of early American radium therapy. The major catalyst for this change was the radium emanation plant, developed for clinical use by physicist William Duane, which collected gaseous radium emanation in glass tubes or needles for therapeutic use. Radium emanation plants required at least a half of a gram of radium, which put them out of the reach of most individual practitioners. The situation in Philadelphia at the end of the 1930s, as shown in Fig. 5.1, demonstrates how radium therapy became a hospital-based therapy, in large part because of emanation plants.

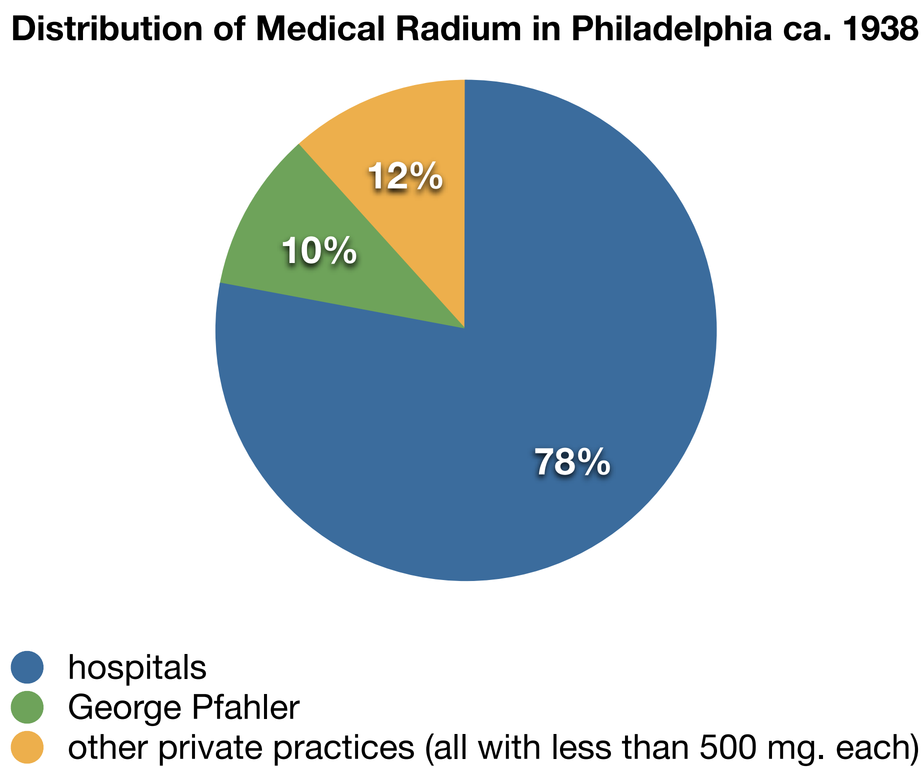

Figure 5.1. Demonstrating the general trend of radium therapy becoming a hospital based therapy, hospitals held the overwhelming majority of medical radium in Philadelphia. Only one individual physician, leading radium therapist George Pfahler, had over a half gram of radium for his practice, the minimum needed to run an emanation plant. From notes, ca. 1938, of Philadelphia radium salesman and consultant Frank Hartman: "Approximate Amount of Radium in Philadelphia" and "Radium Sold in Philadelphia by Mr. Hartman," Folder 3, Scrapbook 1, Box 2, Series 2 and 3, Frank J. Hartman Papers, 1904–1907, The College of Physicians of Philadelphia, Historical Medical Library.

Emanation plants required oversight from hospital physicists, a newly-created position which was not merely technical but involved consultations with radium therapists about dosage decisions. The physicists to whom physicians had reached out in the first period were professional researchers or professors, many who had with an interest in medical applications. In the second period, a handful of interested physicists chose a new career path: working beside physicians as hospital physicists.

Radium therapy's move into hospitals was also dependent upon the medical community acceptance. The professionalizing efforts of radium therapists were bolstered by connections with physics and physicists. Rhetorical claims to authority were supported by the respect given to physics and other laboratory sciences. In the second period, radium therapists also insisted that physics knowledge and connections with physicists were essential for physicians hoping to enter the field. Discoveries in physics, like the existence of secondary radiation or the introduction of the emanation plant, improved the efficacy of radium therapy when thoughtfully folded into methodology, and this did much to help American radium therapy become an accepted hospital therapy.

Avenues for Future Research

The traditional historiography identifies therapies based on radioactivity and shaped by interactions with physicists as a post-World War II phenomenon. This study challenges that assumption, demonstrating that physicists and physics knowledge were intimately connected with radium therapy even before the beginning of World War I. The historiographic bias towards a focus on the Atomic Age is being challenged by scholars like Maria Rentetzi, Matthew Lavine, Vivien Hamilton, and others, and this project is part of this endeavor.

The dominance of radium therapy declined when radioactive isotopes began to be used in therapy. Artificial radioactivity, discovered in 1934 by Irène and Frédéric Joliot-Curie, allowed radioactive isotopes of naturally stable elements to be produced in the laboratory. These radioisotopes, produced in cyclotrons, are treated identically by the body's biochemical pathways as their non-radioactive counterparts and can therefore be used to target specific organs for treatment or certain processes for tracing. Cyclotron-produced radioactive iodine, for example, can be used to deliver radiation almost exclusively to the thyroid, which naturally collects iodine. Radioisotopes began to be used widely after post-World War II cyclotrons and reactors produced them in large supply, but a few centers began experimental radioisotope therapies before the war. Chief among these was the cyclotron at Berkeley, where its inventor Ernest Lawrence collaborated with his physician brother John Lawrence. Their collaboration has been studied, for example by John Heilbron and Robert Seidel, but not with an eye towards the precedent for physicist-physician cooperation set by radium therapy.[429] This study has demonstrated the variety of ways physicians relied on physicists and physics knowledge, and it is worth analyzing what changed and what remained the same when new teams of physicians and physicists began using a new source of radioactivity in therapy.

This project also opens up a way of looking at such physical therapies as electrotherapy, roentgenology, and other therapies of this era that were based on physics, and have traditionally been studied with a focus on physicians. Putting the exchanges between physicians and physicists in a central role may well illuminate new facets of these therapies.

By studying the first decades of American radium therapy and placing interactions between physicians and physicists and physics at the heart of the analysis, this dissertation has demonstrated the important roles physicists played in the development of the field. Far from being a post-World War II development, physicists were directly involved in the clinic, in various ways, from the beginning of the century. The

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[429] J. L. Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory* (Berkeley: University of California Press, 1989).

adaptation, by a physicist, of the radium emanation plant from the laboratory to the clinic was a watershed for radium therapy, introducing a more adaptable mode of treatment. The introduction of the clinical emanation plant necessitated the move from private practices to hospitals and the creation of positions for physicists within hospitals. These hospitals physicists worked alongside radium therapists, the closest and most formal collaboration between physicists and physicians in a field of therapy in many ways defined by its connections with physics from its earliest days.

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