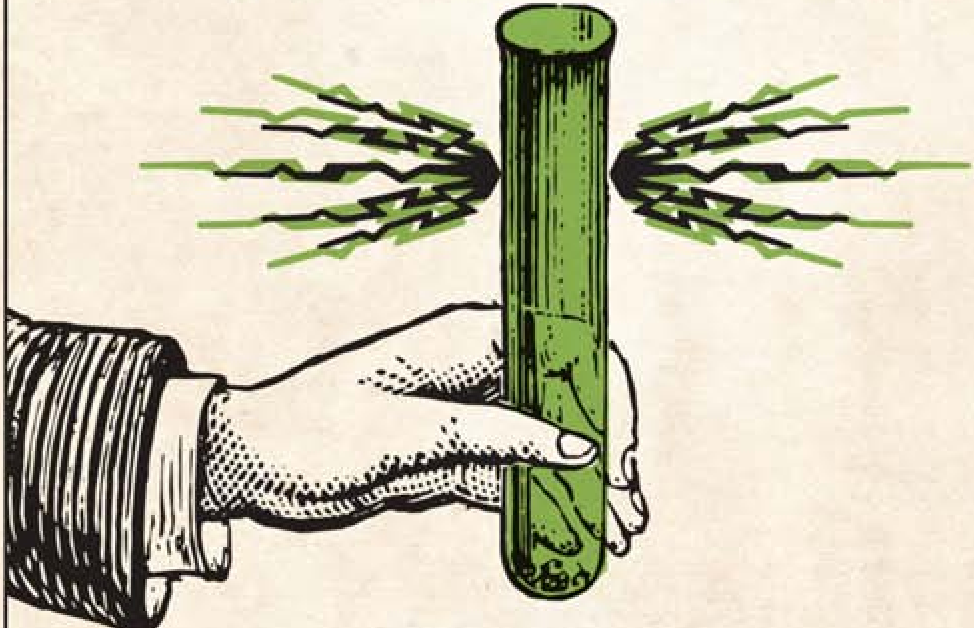
Luis A. Campos

RADIUM

and the secret of LIFE



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Luis A. Campos is associate professor of the history of science at the University of New Mexico.

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To Life!

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Introduction

> The man of science must have been sleepy indeed who did not jump from his chair like a scared dog when, in 1898, Mme. Curie threw on his desk the metaphysical bomb she called radium. There remained no hole to hide in. Even metaphysics swept back over science with the green water of the deep-sea ocean and no one could longer hope to bar out the unknowable, for the unknowable was known.
>
> **—Henry Adams, *The Education of Henry Adams: An Autobiography***

Unfathomably rare and intensely powerful, glowing in the dark and utterly unaffected by any outside force of nature as it gave off rays of unprecedented energy, radium was perhaps the most wonderful and perplexing thing the modern world had ever seen—or had never seen, given that only the barest pinch of pure radium existed at the dawn of the twentieth century. The modern world had certainly heard about radium, however. Helping to overturn established ideas of atomic constitution and atomic behavior even as it gave birth to an immensely popular craze, radium challenged scientist and common man alike, and journalists scrambled to capture all its marvelous implications.

The eighty-eighth element in the periodic table was stunningly and starkly new. For melancholic man of letters Henry Adams, as for many others, the shock was indescribable: "Radium denied its God," he remarked, "or, what was . . . the same thing, denied the truths of . . . Science. The force was wholly new."[1] William James compared the upset caused by the discovery of radium to something like his beginning to "utter piercing shrieks and act like a maniac on this platform" and the doubts this behavior would sow in the minds of his students.[2] Adams, likewise, felt his "historical neck broken by the sudden irruption" of these forces that were both "anarchical" and "little short of parricidal in their wicked spirit towards science"—these rays were nothing like the wholesome, "harmless and beneficent" rays of the solar spectrum. Other phenomena could at least be measured—even "frozen air," if only "somebody could invent a thermometer adequate to the purpose," he said—but the new phenomena of X-rays and the radioactive properties of radium, the two of which seemed to be related in some as yet unknown way, brought about in Adams's mind a new "supersensual world" where nothing could be measured except by the imperceptibles themselves.[3] While the great mathematician Henri Poincaré had called radium a "great revolutionary," for Adams it was simply a sign of "physics stark mad in metaphysics."[4]

Depending on one's cast of mind, the discovery of radium could be said to illustrate the dawning of "a new epoch in chemistry," bringing investigators "nearer than ever before towards getting 'a glimpse of the nature of things,'" as the *Lancet* reported in 1903, or to so challenge preconceived understandings of the world that it was useful for explaining the pragmatic meaning of truth, as James believed.[5] Either way, one of the most striking features of those early years following the discovery of radium is the curious appearance of a metaphysics, and an attendant mode of metaphorical description, that suffused radioactivity with a peculiarly *biological* cast. Not only were radioactive phenomena characterized in quasi-biological ways from the earliest days, by their discoverers and by others, but radium itself—by far the most powerful and most popular of the radioactive elements—was often described as a "half-living" element in scientific and popular texts alike. Radium was sometimes even accorded vitalizing powers, an ascription that became part and parcel of the radium craze that swept the first decade of the twentieth century. While the earliest discoveries in radioactivity were immersed within rich sets of discourse that overdetermined radium's living aura, the popular craze that followed radium's discovery granted vitality and life a radioactive glow all its own.

Long before the hydrogen bomb indelibly associated radioactivity with death, many botanists and geneticists were eagerly remarking that radium held the key to the secret of life. No mere chunk of glowing earth, this most spectacular of elements was also, above all else, an ideal site for unexpected coincidences and fruitful confluences in the life sciences, for an overlapping of discourses and ontologies that persisted throughout the early twentieth century and proved as productive as it was provocative. Cross-fertilizing and recombining, these initially provocative connections between the radioactive and the living propagated over the decades, across disciplines, and between public and scientific discourses. These crossovers led to conceptual and experimental consequences and involved (at least in passing) many of the major biological questions of the day: the origin of life, the physiological effects of radiation, the nature of mutation, and the structure of the gene.

Emerging at a particular moment at the turn of the century and weaving together already-extant discursive strands and experimental traditions aimed at modifying and understanding life, this intersection between the physical and the biological—between the radioactive and the living—transmuted over the first half of the twentieth century, throwing off various new experimental systems and approaches. By critically engaging with the texts, narratives, and images generated both by scientists and by commentators of the day, I follow the varied and intertwining ways by which radium "came to life," how it played a significant role in the history of biology in the early twentieth century, and, in particular, how it contributed in surprisingly revealing and novel ways to the history of genetics.

Although it emerged in the context of the radium craze at the dawn of the century, this distinctive and provocative overlapping of metaphor and metaphysics, of terminology and technique, and of the living, nonliving, and even half-living proved remarkably productive in experimental terms and ultimately led to key insights into the origin of life, the nature of mutation, and the structure of the gene. Four revealing case studies form the core of my analysis as I examine how radium served for successive biological experimenters as vitalizer, stimulant, mutagen, and analytic tool.

This history does more than cast the established narratives of classical and radiation genetics in an entirely new light. In telling the story of how radium remained an epistemic tool, even as it eventually ceased to be an experimental one, I recount in later chapters how this powerful reworking of radium's role contributed to a crucial and widely recognized, but heretofore unanalyzed, shift in the meaning of mutation itself, from organism and chromosome to gene. Radium was thus not only a primary and vital part of the arsenal of early twentieth-century mutagens, but also played a constitutive role in the historical genetic "redefinition" of mutation, a redefinition that in turn, to date, has helped to obscure the central place of radium in the history of classical genetics.

Moreover, as the role of "atom of life" shifted from radium itself to microbes, mutant organisms, chromosomes, and finally genes, the trope of the "secret of life" moved ever inward. From the initial discovery of the new element in 1898 to the putative discovery of the "secret of life" with the elucidation of the structure of DNA in 1953—a midcentury moment by which the ties that had once bound metaphor and experimental practice together so tightly had decayed to mere discursive residues—this study traces the half-life of this transmuting connection between radium and life.

An introductory chapter sets the stage, finding the roots of this powerful association between radium and life in the earliest biological metaphors and metaphysics of early radioactivity research; in preexisting discursive traditions and popularization practices relating heat, light, electricity, thermodynamics, and notions of a "living atom" to life (all of which were easily subsumed under the new radioactive umbrella); in the popular radium craze of the first decade of the twentieth century; and in the aftermath of controversy regarding other types of rays supposedly produced by living things. Radium, in short order, became *the* living element: the element of choice not only for biological metaphors in a new realm of physics, but even for biological application.

Radium's presence in biology was to prove as striking as it would later be subtle. The first case study (chap. 2) examines the early apotheosis of these connections between radium and life in claims emanating from the Cavendish Laboratory at Cambridge that life had been *produced* from radium. John Butler Burke's controversial work, which comprised some of the first experimental work on the origin of life, wove radium into the history of life on the primordial earth and proved to be a key reworking of the history of spontaneous generation. In a series of sensational experiments that involved plunking a bit of radium into a petri dish of beef bouillon, Burke claimed to have produced cellular forms that were, if not quite living, at least *lifelike*. Appearing to grow and subdivide over a span of days and demonstrating other lifelike phenomena at the cytological level, they nevertheless decayed in sunlight and dissolved in water. Half radium and half microbe, these "radiobes" proved both immensely popular and immensely controversial. In that chapter I examine the ways in which Burke's work not only proved pivotal in the redefining of "spontaneous generation" in the Anglophone context, but also served as a founding moment in the history of experimental research into the origin of life that has to date been routinely overlooked. Burke's work explicitly linked the discourses of cosmic and organic evolution with concrete experiment for the first time with an element that appeared to bridge the two realms. Revealed at the height of the radium craze, Burke's findings also demonstrated the rapid sedimentation of the vitalistic metaphors surrounding radium. Not only reminiscent of life, radium itself, quite literally, vitalized matter.

Burke's spectacular claims offset the other, more respectable uses to which radium was also put in understanding basic biological phenomena. The second study (chap. 3) examines how botanical investigators in the early twentieth century used radium to induce or control biological evolution. Explicitly linking the transmutation of the physical species of radium with the transmutation of biological species, Daniel Trembly MacDougal and Charles Stuart Gager of the New York Botanical Garden and the Brooklyn Botanic Garden, respectively, independently irradiated plants with radium in an attempt to study its physiological effects as well as to provide experimental confirmation of Hugo de Vries's new "mutation theory." One of the dominant evolutionary accounts of the early twentieth century, de Vries's theory was widely seen as providing a mechanism for speciation where Darwinism had failed, and de Vries himself had suggested that radium and "the rays of Röntgen" might be useful in inducing mutations—a suggestion that was rapidly taken up. Metaphors of radium's powers were put to the experimental test at this moment and passed. Even those plants that happened not to mutate were seen to have been "stimulated" by radium, which "accelerated" their growth toward an "early senescence." What in a later nuclear age would be a clear sign of damage was—in the ongoing dynamic interplay between popular and scientific understandings of radium's biological effects—clear proof of radium's relevance in the novel early twentieth-century quest to induce and ultimately control evolution.

The third case (chap. 4) turns to further attempts along these lines made by two of the leaders of classical genetics: the Columbia University geneticist T. H. Morgan, best known for his work on the fruit fly *Drosophila melanogaster*, and Cold Spring Harbor investigator Albert F. Blakeslee, who would later become the second director of the Station for Experimental Evolution. Morgan focused on animals and on the use of radium in producing phenotypic mutants that could be attributed to mutant genes; Blakeslee, by contrast, focused on plants and on the use of radium in producing phenotypic mutants that were demonstrably shown to be chromosomal, and not simply genic, in nature. Morgan had turned to radium after having tried a number of other unsuccessful techniques to induce mutations in *Drosophila*, and he succeeded in his quest at nearly the same time as his friend and colleague, Jacques Loeb. Though Morgan later disowned his own claim that radium had been responsible for the mutants he discovered, his discounting of Loeb's mutants—and Loeb's dismissal of Morgan's findings in turn—presents a curious state of affairs that reveals how shifting ideas about radium's effects were inextricably related to ongoing shifts in the understandings of the artificial induction of "mutation." Blakeslee's experiments with radium, for example, established to widespread acclaim that new species could be produced by what he called *chromosomal mutation* (or "chromosomation"), and that this was as important a mechanism of evolutionary change as the *genic* mutation with which the drosophilists were more familiar. Blakeslee's work thus provides a key instance of the use of radium not only in attempts to confirm de Vries's mutation theory, but also to investigate in deeper cytological detail the ways in which induced mutation could occur in a suitable model organism. Although heretofore relatively unstudied by historians of genetics, Blakeslee's work shows how radium was instrumental not only in attempts to understand the physical nature of mutation, but also in what his contemporaries called "experimental evolution" or "evolutionary engineering" (Blakeslee himself would later refer to the emergence of a "genetics engineer").[6] The work of both Morgan and Blakeslee shows that radium remained a central experimental mutagen even as its precise role in inducing mutations—once so clear—came under increasing scrutiny as geneticists began their radium-inspired work on "artificial transmutation."

The fourth case (chap. 5) focuses on Hermann J. Muller's legendary "artificial transmutation of the gene," which has frequently been presented as the origin of the modern study of induced mutation. What is less well known is that Muller came to his researches through his fascination with the powerful metaphorical and metaphysical connections between radium and life that he encountered as a young man. Muller ultimately reworked these tropes to suggest that mutation and transmutation were fundamentally connected and that radium could be useful to produce not only phenotypic and chromosomal mutants, but mutations at the most fundamental level of all: the genes. In seeking to more precisely characterize the nature of mutation in *Drosophila*, Muller began with radium before shifting to X-rays as his mutagen of choice by the late 1920s. This shift was due to technological advances in the delivery of X-rays—the two radiations were increasingly being equated in their physical nature and in many of their biological effects by the mid-1920s—as well as to contingent circumstance, as Muller's vial of radium broke during a hot train ride through Texas in 1924. Muller's landmark 1927 announcement of his spectacularly precise and detailed new methods for the "artificial transmutation of the gene" ultimately earned him the Nobel Prize.

Radium was thus not only a primary and vital part of the arsenal of mutagens used by early twentieth-century researchers—from MacDougal, Gager, and Morgan to Blakeslee and Muller—but also played a constitutive role in the crucial and widely recognized, but heretofore unanalyzed, historical redefinition of "mutation." In his shift from radium to X-rays, and from transmission genetics to transmutation genetics, Muller ended up radically recharacterizing what had been a pluralistic set of understandings of "mutation" as a fundamentally genic phenomenon. This shift in the meaning and referent of "mutant" and "mutation"—from organism to chromosome to gene—not only marked the beginning of the end of a multilevel, nuanced understanding of mutation and its replacement by a fundamentally genic theory of mutation, but also ended up distancing radium from life in experimental terms. As the γ-rays of radium were increasingly understood by biologists to have the same effects as X-rays (physicists had long since equated the two), Muller's focus on the gene as the proper target for mutation and the X-ray as the proper tool for inducing it became a sentiment and a practice more widely shared. By the 1930s, X-ray-based "radiation genetics" had largely, but not entirely, replaced the use of radium in the study of the structure of the hereditary elements, and a larger "radiobiology" was still to come. This turn away from radium and toward other sources of ionizing radiation contributed in turn to the forgetting of the important role of radium in the successful earlier work of Gager, Blakeslee, and various others—work that Muller had encountered and studied on the path to his own remarkable experiments. Such was the aftermath of using radium as an epistemic, and not only an experimental, tool.

The fact that Muller's radioactive metaphysics of the gene, inherited from this earlier work with radium, could contribute to this process of historical rewriting shows further ways in which the powerful association between radium and life continued to transmute over the course of the first half of the twentieth century. The case of Muller is thus neither the zenith nor the end of the tale, but a fascinating inflection point: the collective forgetting of radium's early role is a consequence of the same processes of interpretation that permitted radium and life to become so closely associated in the first place. It is also reflective of the same historical processes that enable us to find and to trace this powerful association over the decades of this story. There is thus more to this account than the mere uncovering of the many and varied transmutations and disintegrations of the long-standing and powerful association between radium and life, or a series of disconnected musings on remarkable metaphors in a particular corner of biology.[7] In fact, studying the ongoing transmutations of this powerful association between radium and life across experimental systems, historical actors, and decades can reveal as much about the nature of history as about heredity.

This book is therefore structured to be read at two levels. At one level, it is a series of straightforward case studies on the applications of radium in biology—how and why these applications came to be, and how they were eventually lost to historical memory, as just described. These fascinating stories about radium—a kind of "prehistory of radiobiology"—not only uncover heretofore unknown but important dimensions of radium's life in biology, but also help to revise canonical moments in the early history of genetics. But at another level, the book is also a novel experiment in historiographical form in that it seeks to treat "radium" not only as the subject of the book and as an object that life scientists discussed and worked with, but also as the narrative conceit and immanent analytic for the book as a whole. In a manner broadly analogous to the ways in which the properties of radium inspired, structured, and sometimes disrupted the experiments of early physicists, botanists, and geneticists, I hope to reveal how reflexively taking "radium" seriously as an immanent analytic—tracing key moments of transmutation in the long half-life of radium's association with life—can inspire, structure, and ultimately challenge a historical argument through dynamics of transmutation and decay similar to those that were at work for the historical actors themselves. Their struggles with the intersection of radium-based radioactive discourse and experimentation are not fundamentally different from those encountered by the historian seeking to narrate the half-life of such a connection.

And so a word about half-lives. *Radium and the Secret of Life* is thus also an exploration of how to write about the intersection of the worlds of the radioactive and the living in the first half of the twentieth century without relying on all-too-familiar biographical tropes and metaphors such as the "life and death" of an element. Splitting the difference, the trope of the half-life serves as a narrative tool that suggests what it might mean for radium to serve as an immanent analytic in a historical account. Radium and life were powerfully and closely associated with each other as early as 1904, both in the public imagination and in scientific terminology and experimentation. How far did this association extend, and how long did it last? It began with a sharp initiatory moment (which was itself a perpetuation of and refraction of earlier entities and analogies) and has since intermittently decayed toward—but has never quite reached—a leaden state of complete dissociation. By tracing this asymptotic process of decay, and in ultimately coming to a point in the Conclusion where *it is no longer clear* whether the historical evidence speaks to a still-extant connection between radium and life, I hope to explore the possibility of a more consciously reflexive history—one in which the radiant narrative itself comes to test the limits of evidence and argument.[8]

In the final chapter (chap. 6), therefore, I explore the afterlife and persistence of radioactive residues in Muller's later work, in that of his contemporaries, and in the larger context of the study of heredity in the 1930s and 1940s. In these cases it becomes increasingly less clear whether there is any legitimate connection to be drawn to these further transmutations, decays, and disintegrations of what were once powerful associations between radium and life. In recounting this history, with its countless possible historical residues, *Radium and the Secret of Life* thereby challenges the very idea of any neat historical narrative of the "life and death" of radium's role in biology. In a theoretical coda, I suggest that this is what a hermeneutic of transmutation, seriously attempting to deploy "radium" as an epistemic tool for the historian as much as it was for the scientist, might look like in the form of historical narration. In short, as the experimental productivity of the once all-powerful metaphorical and metaphysical association between radium and life slowly decayed to trace residues (and tracers) in a generalized background of radiobiology, the once-pronounced clicking of the Geiger counter of historical narrative slowly merges into noise.

Throughout this study, I therefore consciously draw on Hans-Jörg Rheinberger's treatment of the *historial* and what he has called the "temporal structure of the production of a trace."[9] In his masterful empirical and theoretical analysis of "experimental systems," Rheinberger traced the emergence into scientific reality of "epistemic things" from the articulation and composition of "traces."[10] The traces in the story of radium and the secret of life, however, are inverted—they do not lead up to an epistemic thing, but rather away from a powerful originary moment when radium and life were clearly and commonly associated, when the secret of life clearly had something to do with radium. And so, after tracing a path from radium and its intersections with the spontaneous generation of life (Burke) to the cell (MacDougal) to the chromosome (Blakeslee) and to the gene (Muller), by way of a theoretical coda, I explore how, as discursive tropes and material agents alike continued to transition from radium to other sources of ionizing radiation, this initially powerful association of radium and life continued to disintegrate. Initially so rich with metaphor and metaphysical association, the connection between radium and life bifurcated into increasingly instrumentalized or metaphorical traces such that only distant but tantalizing echoes of its power remained. Just as investigators and commentators at the turn of the century had once held that the discovery of radioactivity entailed the unveiling of the "secret of matter," the ascription of the "secret of life" to the structure of DNA upon its discovery in 1953 can be viewed as one of many remaining radioactive residues in the midcentury disarticulation of radium and life some fifty years after their first powerful association—a well-known and convenient ending place for a story that, in approaching an asymptote, otherwise has no easy and neat narrative ending.

Interlinking metaphors and metaphysics, preexisting discourses and novel experimental ontologies, this story, then, in more ways than one, is the story of how radium came to life—and of how life came to radium. The element of choice for bringing together the realms of the radioactive and the living, radium was the atom of life and yet contained within itself the seeds of its own decay. This study thus seeks to reveal the changing particulars of this powerful association between radium and life over the decades and across experimental systems in order to illustrate how, as experimental productivity eventually outpaced metaphorical and discursive resonance, an initially unified coherence between "radium" and "life" was lost. Interacting with dominant conceptual frameworks, technological realities, and living organisms as this association generated a series of energetic and ever more productive experimental approaches, this initially powerful resonance between radium and life decayed to trace residues in a generalized background of radiobiology. Time after time, as the first half of the twentieth century unfolded, this nexus between radium and life—in a variety of directions and manners—transmuted.

1 The Birth of Living Radium

While uranium and thorium had already been known for decades, and while their newfound radioactivity catapulted them to greater prominence at the end of the nineteenth century, it was only with Marie Curie's discoveries of polonium and especially of radium, and with Ernest Rutherford and Frederick Soddy's subsequent theory of radioactive decay, that the new science of radioactivity took off—and with it an intense new culture of fascination with radium. The turn of the century saw the birth of a metaphorical (and sometimes more than metaphorical) understanding of "living radium."

For an age when chemistry and physics were thought to be closing in on the last few secrets of nature, the back-to-back discoveries of X-rays and of radioactivity came as a complete surprise. Curie's famed discovery had followed immediately after Wilhelm Roentgen's initial discovery of the penetrating power of X-rays in 1896 and Henri Becquerel's accidental discovery of the radioactive properties of uranium shortly thereafter. Dredging through tons of Joachimstal pitchblende to obtain the smallest fraction of radium in 1898, Curie had found with radium the radioactive element par excellence, some millions of times more radioactive than uranium. Incredibly rare and precious, even in minuscule amounts radium dazzled, glowing in the dark and shooting off rays in a seemingly endless blast of energy that came from nowhere in particular. As Rutherford later recounted, "The name radium was a very happy inspiration of the discoverers, for this substance in the pure state possesses the property of radio-activity to an astonishing degree."[1] In comparison, Roentgen's and Becquerel's discoveries had made nowhere near the impact on the public.[2] When Curie finally succeeded in isolating radium in a pure state in 1902, granting incontrovertible proof of its elemental status, radium was already well on the way to becoming the all-powerful and wondrous new element that could do everything—and that soon enough could do no wrong.

The peculiar connection between the phenomena of radioactivity and the properties of and discourses surrounding life first began to emerge in those earliest days of the science of radioactivity with Ernest Rutherford and Frederick Soddy's discovery that radioactivity, in fact, indicated the transmutation of the elements. Elements were supposed to be the fundamental building blocks of the physical world, the basic level of atomic composition of all things. "Atomic" literally meant that which could not be subdivided. A substance that had all the hallmarks of an element, that fit an empty spot on the periodic table, and yet came apart, spontaneously, was—prior to the discovery of radioactivity—almost inconceivable. "Elements" simply did not permit subdivision. The discovery of the transmutation of atomic species proved to be nearly as problematic a revelation for Rutherford and Soddy as the transmutation of biological species had once been for Darwin.

For all its mythical status, Rutherford and Soddy's legendary collaboration lasted only a year and a half. Beginning in 1901, when they both found themselves at McGill University—Rutherford an established professor of physics, Soddy an up-and-coming young chemist—their "local and intense" collaboration resulted in the production of nine papers, the last of which, "Radioactive Change," appeared in May 1903 and presented their theory in its final form. Their famed collaboration not only brought forth the first solidified account of elemental transmutation—the "disintegration theory of radioactive transformation"—but also served to explain many of the other radioactive properties of the radioelements and to advance the idea of an evolutionary history of the universe told by its elements.

The *experimentum crucis* that led to the birth of the disintegration theory of radioactive substances took place in April 1902, when Rutherford and Soddy observed thorium X spontaneously changing within the confines of their laboratory setup into the noble gas argon. Soddy, though no alchemical adept, had nevertheless always been interested in the connections, historical and otherwise, between alchemy and chemistry and had even lectured on alchemy in his course on the history of chemistry: "I made that goal [of transmutation] quite clear," he said. The appearance of alchemical transmutation before his very eyes, however, was almost "too devastatingly simple." He recalled himself "standing there transfixed as though stunned by the colossal import of the thing."[3]

> I remember when I interpreted my first experiment I could not wait to tell Rutherford, but words would not come. I could feel my heart throbbing, and as though propelled by some outside force I heard myself utter unbelievable words: "Rutherford, this is transmutation!"

Rutherford, "in his breezy manner," is said to have shouted back: "For Mike's sake, Soddy, don't call it *transmutation*. They'll have our heads off as alchemists."[4]

Soddy, however, remained transfixed by the idea of elemental transmutation. Once disparaging of earlier attempts at alchemical transmutation, he now found himself converted. In short order, he publicly declaimed in a lecture at McGill that "alchemy must be regarded as the true beginning of the science of chemistry." Accordingly, he said, transmutation "is, as it has always been, the real goal of the chemist." From doubtful practicing chemist-cum-historian of alchemy to firm adherent, Soddy came completely around[5] and found himself "entirely engrossed" in interpreting his newfound transmutation:

> The atoms were disintegrating, so disposing of the chemists' cherished theories of its immutability. I began to consider the state of the disintegrated atom. Was it now a smaller atom of the same element? By its integration would it have assumed another character, become another element? By further possible emissions would it further disintegrate and if so, at what rate? How long would such a disintegrating atom live? Since it seemed obvious that most of the atoms in the element would at some time be suffering disintegration it followed that the element would be composed of atoms in various stages of disintegration.[6]

Soddy recollected Rutherford afterward "taking me to task because people were saying that what we were saying was tantamount to 'transmutation,' and I had to convince him that it *was* transmutation and put him *au fait* with the chemical evidence to confute anyone who disputed it." Transmutation still smacked too much of the alchemical for a respectable scientific report, however, and in the first published account of their discoveries in April 1902, the word "transmutation" was replaced with the more benign "transformation."[7] Yet the excitement of their alchemical discovery still bubbled beneath the surface: in an effort to get their first paper published in the *Transactions of the Chemical Society*, Rutherford had written privately to Sir William Crookes, saying that "although of course it is not advisable to put the case too bluntly to a chemical society, I believe that in the radio-active elements we have a process of disintegration or transmutation steadily going on which is the source of the energy dissipated in radioactivity."[8] Nevertheless, the shift to "transformation" as the term of choice was rapid—by September of that same year, Rutherford and Soddy reported in the *Philosophical Magazine* that radioactivity was "a manifestation of sub-atomic chemical change" and, as such, "the radioactive elements must be undergoing spontaneous *transformation*."[9] From here on out, a distinction emerged between rather more scientific references to "disintegration" and "transformation" and what were clearly more popular references to "transmutation"—although Soddy continued to blur the lines from time to time.

With their different disciplinary interests, it was only natural that Rutherford and Soddy would pursue different paths after their discovery. Rutherford, the physicist with "a most radiating smile," focused on further experimentation aimed at discovering the nature of the α-particles produced in moments of radioactive transformation.[10] Soddy, the chemist, focused more on the chemical implications of the new discovery and looked for further proof of transmutation. While Rutherford remained at McGill until leaving for Manchester in 1907, Soddy had already transferred to William Ramsay's laboratory at Cambridge by 1903. Soddy found his first samples of radium by chance one day in April of that year as he walked "past a store [Isenthal's] on Mortimer Street off Upper Regent Street" in London. A sign in the window read: "Pure radium compounds on sale here." At a time when radium was available only "by favour of the Curies," as Soddy recalled, this was an exceptional find: "Here it was to be bought in a London shop at some eight shillings a milligram of pure radium bromide," the product of a German production firm (Geisel of the Chinin Fabrik of Brunswick) that had begun to manufacture radium compounds on a commercial basis.[11]

The final proof of transmutation thus came in Ramsay's laboratory with the production of helium from the radium sample on April 27, 1903.[12] The result of Ramsay and Soddy's collaboration, one commentator noted, was nothing less than "the chemical sensation of the summer of 1903."[13] The presentation of the proof of transmutation at the annual meeting of the British Association for the Advancement of Science in Southport in 1903 came at a time when Lord Kelvin was still espousing the idea that it was the ether that carried energy to radioactive substances, rather than seeing such energy as something inexplicably inherent in the atom.[14] By 1903, however, general agreement was beginning to fall in favor of the Rutherford-Soddy account of radioactive transformation. The only significant holdouts against the theory of radioactive transformation in the British context, it turns out, were Kelvin and Henry E. Armstrong. Armstrong attacked the disintegration theory, "which assumes that nature has endowed radium alone of all the elements with incurable suicidal monomania," but both men were largely silenced after Rutherford's presentation.[15] The physics of the new phenomenon of radioactivity was beginning to come together.[16] The broader cultural and biological import of radium, however, was just beginning.

"Physics Stark Mad in Metaphysics"

"In pre-radium days," W. Hanna Thomson remarked in his popular 1909 *What Is Physical Life? Its Origin and Nature*, "we took the diverse chemical elements for granted, with vague speculations as to their possible evolution from some primitive kind of stuff out of which the fabric of the world has been spun." But the discovery of radioactivity, he went on, "has made it certain that one element can be evolved from another, or, in other cases, legitimately thought of as evolved from another, by the addition or separation of certain components."[17] Whether or not Thomson's description of the phenomena of radioactivity is technically accurate, what is certain is that the work of Rutherford and Soddy took what had previously been a merely suggestive connection between the processes of cosmic and biological evolution and linked the two much more closely. From Robert Chambers's all-encompassing *Vestiges of the Natural History of Creation* of 1844 (which continued to outsell Darwin's *Origin* even years after the latter's publication in 1859) to the work of Herbert Spencer and others, many in the nineteenth century readily viewed evolution as a simultaneously cosmic and biological process.[18] While elements in everyday experience may have been stable, the idea that elements—much like living things—at some point in the history of the cosmos underwent an evolutionary process was considered sample content of Radium and the Secret of Life

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