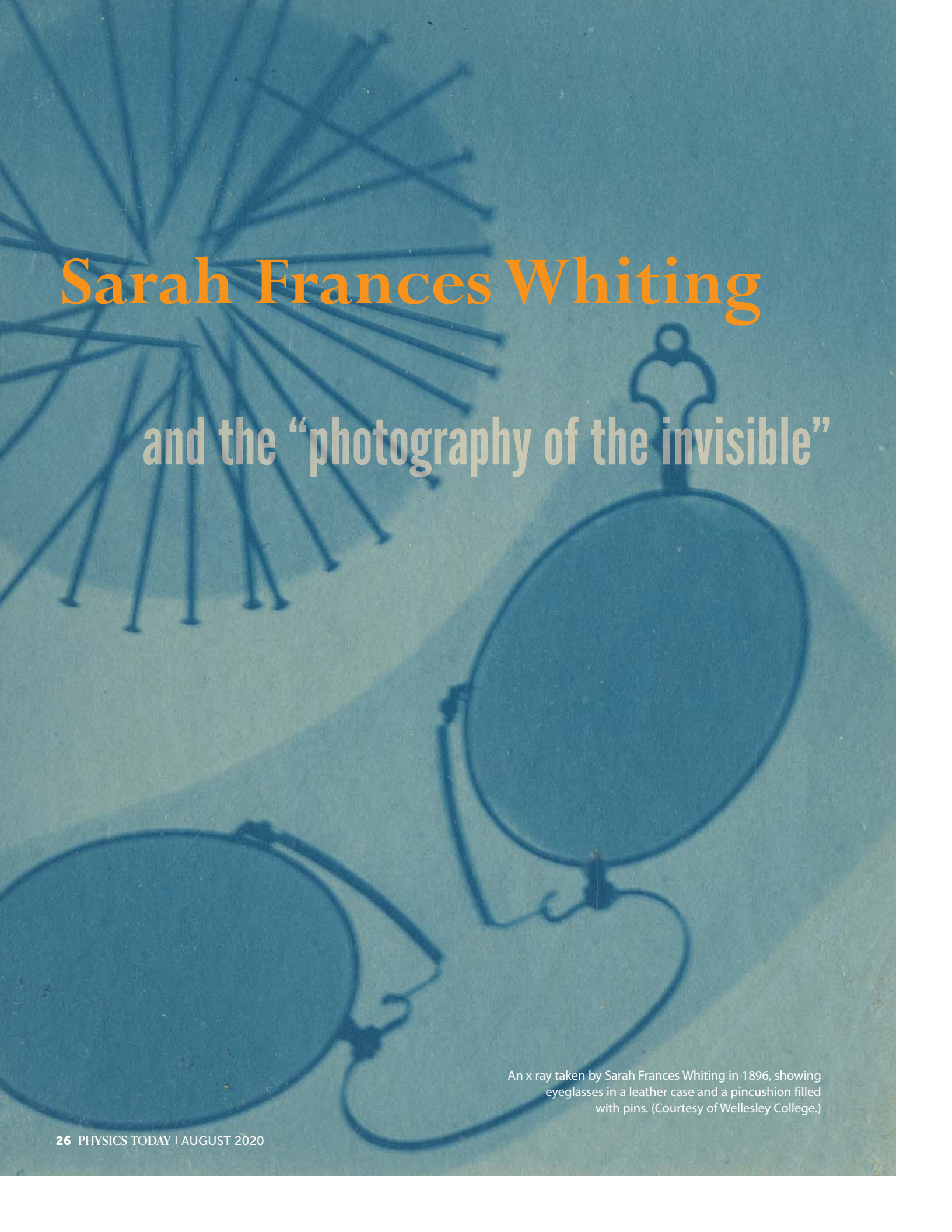




Sarah Frances Whiting

and the “photography of the invisible”

An x ray taken by Sarah Frances Whiting in 1896, showing eyeglasses in a leather case and a pincushion filled with pins. (Courtesy of Wellesley College.)

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John S. Cameron and
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A team of women working in the physics laboratory at Wellesley College carried out some of the first successful x-ray experiments in the US.

In February 1896 Sarah Frances Whiting, founder of the physics and astronomy departments at Wellesley College, conducted a series of x-ray experiments. She was working only a few weeks after the public announcement of Wilhelm Röntgen's discovery of the rays, and she was not alone; amateur and professional scientists at colleges, universities, and medical centers across the US were attempting to replicate and extend Röntgen's results. But Whiting (see figure 1), who enlisted the assistance of a Wellesley colleague and several students, was among the first to do so successfully. Even more importantly, Whiting was the first woman—and almost certainly the first person, male or female—to do so in an undergraduate laboratory. Her original glass plates from the experiments do not survive, but 15 photographs printed from them (see the opening image of one such photo) were recently rediscovered in a campus building slated for demolition. They provide a vivid reminder of Whiting's success.

The x-ray experiments were only one instance in which Whiting drew on her keen engagement with contemporary scientific advances to offer her students an experience available to few undergraduates at the time, and to almost no women. Throughout her long career, Whiting introduced thousands of women to physics and astronomy, both fields then associated almost entirely with men. Her pedagogical efforts led many of her female students to pursue their own careers in the sciences.

Wellesley, Whiting, and a new science pedagogy

Philanthropists Pauline Fowle Durant and Henry Fowle Durant founded Wellesley College in 1870 as an educational experiment. At that time there were few options for women to pursue higher education in the US, and the Durants decided to use their significant wealth to provide women students and

faculty with the same opportunities available to men.¹ Finding faculty, however, was a challenge. With few exceptions, the first generations of Wellesley faculty were female, single, and characterized as spinsters in the parlance of that time. It was a common belief that married women had obligations at home that should keep them out of academia. Even Wellesley's popular second president, Alice Freeman, had to step down when she married in 1887. Faculty lived on or near campus, often with their mothers or sisters; Whiting, for instance, lived with her sister Elizabeth, who was also on the Wellesley staff. In some cases, Wellesley faculty lived with other women in mutually beneficial relationships, some platonic and some not, that Henry James and others in the late 19th century called Boston marriages.

As one of only a few institutions of higher learning in the



FIGURE 1. SARAH FRANCES WHITING (1847–1927) USING A FLUOROSCOPE to examine the bones in her hand in Wellesley College's physics laboratory, circa 1896. On the table in front of her is a Crookes tube mounted on a stand and an induction coil to modulate the voltage. (Courtesy of Wellesley College.)

US that both employed and educated women, Wellesley quickly became a haven for progressive female intellectuals. Faculty were engaged in all aspects of college life and worked together to establish a rigorous curriculum like those taught at contemporary men's colleges. But there was also a conscious attempt to set Wellesley apart from other educational institutions. Henry Durant was quoted as saying, "If we were like other colleges we should not be what we ought to be."²

But establishing a successful college for women wasn't easy. Most female students in that era came to higher education with less training than their male counterparts, and significant numbers of them withdrew before earning their degrees, whether to marry or due to other social pressures. Although 246 women matriculated in Wellesley's first class in 1875, only 18 graduated four years later. To combat attrition, the Durants established a preparatory school to ready students for college-level work. They also expanded the curriculum to encompass a wider range of subjects, providing employment opportunities for scholarly women in numerous disciplines. From 1875 through at least 1921, for example, Wellesley employed far more female scientists than any other institution of higher education in the country.³

One of the most prominent Wellesley scientists was Whiting, who was hired to teach physics in 1876. We know a great deal about Whiting from her own writings and from obituaries

written by her most famous student, astronomer Annie Jump Cannon, class of 1884.⁴ Whiting had been interested in science from an early age, in part due to the influence and encouragement of her father, a teacher himself. After earning a BA in 1864 from Ingham University in Le Roy, New York, she began teaching mathematics and classics at a girls' secondary school in Brooklyn. Whiting had no graduate training in the sciences—relatively few of her Wellesley colleagues did in those early years—but she attended lectures to further her education and made enough of an impression on the educational community to attract the Durants' attention. They offered her a position at Wellesley and arranged for her to spend her first two years visiting colleges and universities in and around New England.

During those years, Whiting became the first woman to attend Edward Pickering's physics classes at MIT. Pickering's novel, hands-on method of laboratory instruction made a strong impression on the Durants and on Whiting, and Whiting used it as a model to devise her own physics curriculum. Like Pickering, Whiting required her students to design and conduct

laboratory experiments. That practice aligned well with Wellesley's efforts to encourage students to be actively engaged in their own learning, and it spread quickly to other disciplines. The college developed the first undergraduate laboratory for comparative anatomy in the US, and under the leadership of Alice Van Vechten Brown, art history students learned and practiced historical artistic techniques. Brown's approach made such an impression on other educators that it became known as the Wellesley method when it was adopted elsewhere.⁵

Facilities at Wellesley

The hands-on method of teaching physics required an extensive collection of scientific equipment. Whiting established just the second undergraduate physics laboratory in the country, after MIT, and the first for women. There were few commercial manufacturers of scientific equipment in the US, but with generous funding from the Durants and advice from Pickering, Charles Barker—who Whiting later referred to as her “scientific father”⁶—of the University of Pennsylvania, and others, Whiting secured what she needed. She selected some instruments from the displays of European manufacturers at the 1876 Centennial Exhibition in Philadelphia and commissioned the manufacture of others by providing exacting specifications to New England artisans. When Whiting taught her first physics classes in fall 1878, her laboratories were extraordinarily well equipped with instruments to study sound, heat, electricity, and mechanics (see the box on this page). She also had a full selection of photographic apparatus and sophisticated optical instruments, including a wide range of spectroscopes (see figure 2).

Whiting proved to be a dedicated teacher. She wrote an astronomy textbook—*Daytime and Evening Exercises in Astronomy for Schools and Colleges* (1912)—and multiple articles on science pedagogy, all part of her efforts to train the next generation of female scientists. She also kept abreast of new developments



FIGURE 2. A ROOM IN WELLESLEY'S PHYSICS LABORATORY, CIRCA 1893. The instrumentation includes various electrostatic generators, or Wimshurst machines, Leyden jars, induction coils, and a galvanometer. It was only the second undergraduate physics laboratory in the country, and the first for female students. (Courtesy of Wellesley College Archives, Library & Technology Services.)

PHYSICS FACILITIES AT WELLESLEY COLLEGE

The *Wellesley College Calendar for 1877–8* (page 39) boasted that the physics department had

a convenient lecture-room, with lantern and porte lumière constantly in place for the illustration of lectures, or the projection upon the screen of minute experiments. Water, wires from the battery, oxygen and hydrogen and illuminating gas, are furnished at the lecturer's desk. The costly apparatus for this department has been selected with great care from the best makers in England, France, Germany, and this country. . . . This is arranged in eight separate rooms and alcoves. One dark room is supplied with a Bunsen's Photometer for measuring the candle power of gases, and with apparatus for Spectrum Analysis, etc. Another room is fitted up for an Electrical Laboratory, and supplied with a Wheatstone's Bridge and Resistance Coils, Thomson's Mirror Galvanometer and Lamp Stand, made by Elliot of London, and other apparatus necessary for Electrical measurements. There is also a battery room and a room for photography.

in order to introduce them to her students. She met Thomas Edison and gave a demonstration of his incandescent bulbs to the Wellesley community to persuade trustees to invest in his new technology. She attended classes at the universities of Berlin and Edinburgh and interacted with a wide range of scientists in the US and Europe, both in person and via correspondence. Her travels and meetings with other scientists were a point of pride for Whiting; she later recalled,

I was at a meeting of the British Association in 1881 when Langley's heat spectrum was announced, in 1888 when Section A was discussing the discoveries of Hertz, and again in 1896 when the Xrays [sic] of Roentgen were to the fore and Ramsey gave me a tube of the Helium he had just discovered. At the American Association in 1900 I was present when Nichols announced the verification of Maxwell's prediction that light exerted pressure. . . . In 1896 I was invited, by exception, to visit the laboratories of Dewar at the Royal Institution in London and see the apparatus in action which liquified air. In 1896 also I visited the laboratories of Onnes of Leyden the very week he liquified Helium.⁷

Unfortunately, as women working in what was then very much a man's field, Whiting and other female scientists had to deal with considerable prejudice and limited opportunities.⁸ Near the end of her career, she reflected on “the somewhat nerve-wearing experience of constantly being in places where a woman was not expected to be, and doing what women did not conventionally do.”⁶ Some scientists took an enlightened approach to the presence of women in their ranks. In London, Whiting met Lord Kelvin; in a 1924 article for *Science*, she recalled being impressed when he was “neither surprised nor alarmed” by her gender.⁹ But others were concerned about what might happen to their comfortable worlds if more women entered their fields. When Whiting met William Crookes in 1888, he reportedly mused, “What would become of the buttons and the breakfasts if all the ladies should know so much about spectroscopes?”¹⁰

Whiting must have found Crookes's comment amusing, since she did in fact know a great deal about spectroscopes. She guided her students' laboratory experiments on solar spectroscopy, emission spectra of various metals, absorption spectra of chlorophyll, and, in her Physical Astronomy course, the classification of stellar spectra.¹¹ That knowledge, along with her emphasis on experimentation, led to her success with x rays.

Röntgen and x rays

In November 1895, while observing the spectra created by beams of electrons in a shielded cathode-ray tube, German physicist Wilhelm Conrad Röntgen made a remarkable discovery. An unidentified form of radiation from the tube was passing through solid materials and leaving images—what we would now call a radiograph—on prepared glass photographic plates. After fixing the images with a chemical bath, he used the plates as negatives to make paper photographs that could then be reproduced and circulated. Although other scientists had noticed similar phenomena, Röntgen was the first to explore the physical properties of that radiation, which he named x rays after the mathematical symbol of an unknown quantity. Röntgen published his findings in *Sitzungsberichte der Würzburger Physikalischen-Medicinischen Gesellschaft* (*Proceedings of the Würzburg Physico-Medical Society*) later that year; the editor decided to forgo the customary prepublication lecture as an acknowledgment of its importance.

Although Röntgen wrote in German in a journal with limited circulation, he sent copies of the article and his photographs to colleagues. News of his discovery reached English-language newspapers by 7 January 1896. Additional accounts quickly followed, culminating with translations of Röntgen's paper in both *Nature* on 23 January and *Science* on 14 February. A photograph of the hand of Röntgen's wife, Anna Bertha Ludwig, her wedding ring on her third finger, was a particular sensation.

The ability to render the invisible visible captured the popular imagination in a way few previous scientific announcements had, prompting songs, poems, books, and public demonstrations. (It was not until later, of course, that scientists and physicians realized the risks associated with x-ray exposure.¹²) Prominent physicists all over the world, along with quite a few amateur scientists, rushed to replicate Röntgen's experiments. In 1926 a graduate of Davidson College claimed that he and his classmates had secretly conducted a successful x-ray experiment on 12 January 1896; that claim, however, cannot be corroborated.¹³ The first confirmed successes in the US had the backing of major research universities: Arthur Wright at Yale University on 27 January, John Trowbridge at Harvard University by 29 January, Edwin Frost at Dartmouth College on 3 February, Mihajlo Pupin at Columbia University on 4 February, Arthur Goodspeed at the University of Pennsylvania on 5 February, and William Magie at Princeton University on 6 February.¹⁴



FIGURE 3. SARAH FRANCES WHITING'S COLLEAGUE MABEL CHASE PLACES HER HAND ON A GLASS PHOTOGRAPHIC PLATE, below a Crookes tube, to take a radiograph of the bones of her hand in Wellesley's physics laboratory, circa 1896. (Courtesy of Wellesley College Archives, Library & Technology Services.)

Whiting's x-ray experiments

On 7 February Whiting joined that elite group. It seems likely that Whiting first heard about the discovery from an article in the *Boston Daily Advertiser* on 14 January. The article described Röntgen's equipment—a Crookes tube, an induction coil, and a battery—all of which were readily available in Wellesley's laboratory, along with glass plates, holders, and photographic chemicals.

Whiting was assisted by a colleague, physics instructor Mabel Augusta Chase, who went on to a long career at Mount Holyoke College (see figure 3). In accordance with Wellesley's laboratory teaching methods, the two instructors were joined by at least two students: Cannon, who had returned to take additional classes before continuing her astronomy studies at Radcliffe College and Harvard, and Grace Evangeline Davis, class of 1898, who became a noted meteorologist and taught physics at Wellesley from 1899 to 1936. Together the women experimented with several variables—different objects, equipment, and timings—to produce at least 15 “shadow photographs,” as Whiting described the x-ray images left on the glass plates.

Other than annotations on the reverse of some of the photographs made from those plates, Whiting left no written documentation of her x-ray experiments. However, someone alerted the *Boston Daily Advertiser*, who reported it on 8 February. The *Advertiser* also interviewed Whiting for a longer article that appeared on 11 February. In that piece, she described the results of her experiments at length, explaining her use of different power sources, exposure times, and materials to improve the

quality of her images and investigate the degree to which the rays would penetrate materials of different density.

Additional information about their first experiment comes from a letter Cannon wrote to her cousin Ned Jump. On the reverse of torn sheets of mimeographed lecture notes, Cannon described their efforts in detail:

We took – a photograph this morning by the so-called Röntgen process, or by the Cathode rays. It is not a brilliant negative, but it is there, that's the point. . . . Miss Whiting has been intending to try it, and so concluded to do it immediately. We arranged it very simply thus. A current from four cells was passed through a Ruhmkorff coil, and connected to a Crook's tube. On the table where they were all placed, right under the cathode of the tube, we laid a plate holder horizontally, [glass] slide in. On top of the slide, we placed a pair of pincers, a picture hook, a key. We started the current, and left them all in position one hour and a quarter. Miss Chase + I then proceeded to the dark room to develop. Little did I think there would be anything there to develop! I was somewhat excited, you may imagine. At first, there did not seem to be anything. I covered the plate tight, to beware of fog. The next time I looked, lo and behold there was a light streak, "It's the picture-

hook," we both exclaimed, and so it was, clear and unmistakable. The pincers came out too, but the key did not.¹⁵

Whiting annotated a photograph of the experiment with her name and that of Chase and the following description: "A picture hook + pincers in a wooden box. First attempt. Underexposed but showed that success was attainable with apparatus in use viz a crooks tube [here she inserted a sketch of the tube] made to show molecular shadows. Executed with 6 in coil." That last phrase refers to the six-inch-diameter induction coil visible on Whiting's work bench in figure 1.

Even underexposed, it was a thrilling outcome and gave the women a better sense of how to proceed. Cannon's letter outlined their next steps: "While I am writing to you, we have another [glass] plate, shall I say, exposed. It's the queerest looking exposure you ever saw. A dark paste-board box, with various metallic objects inside is tied onto a plate-holder, [glass] slide in—all standing up before the Crook's tube, while the current is sizzling away. We are going to give it two hours."¹⁵

A few hours later, an exhausted Cannon added another page to her letter. She revealed, "I stayed up to develop the second one + have a good negative. Everything inside the box is good, but there's no sign of the box, no sign of the [glass] slide. I am tired + can not write more."¹⁵

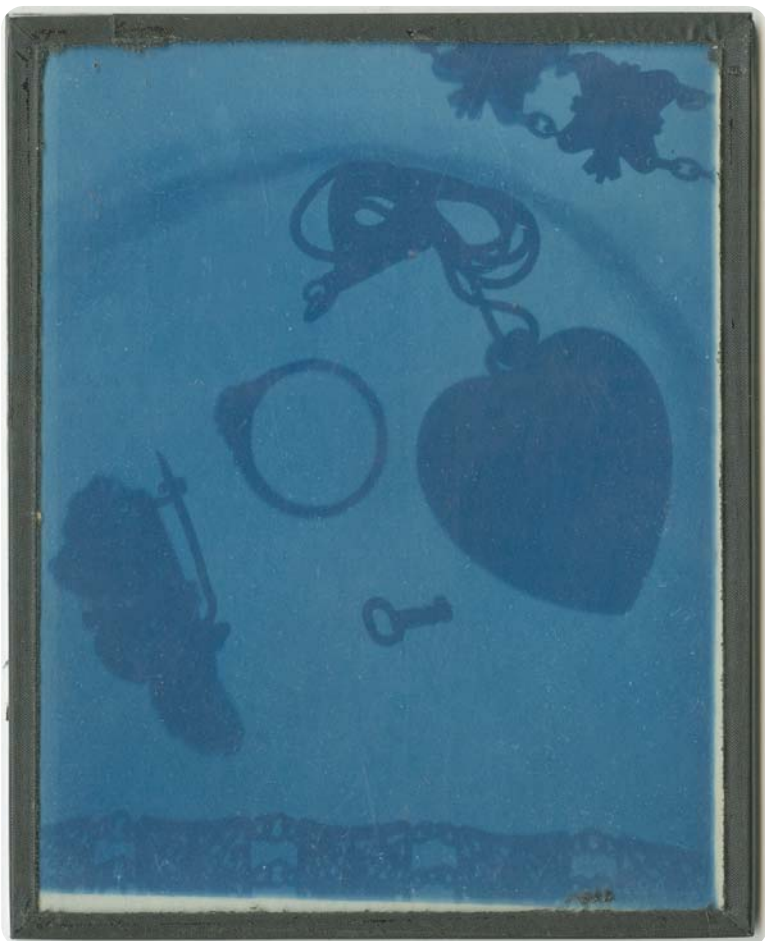
The women made a photograph from that negative too. The objects—a ring, a hook, and two unidentifiable shapes—appeared blurry, but the image was nevertheless an improvement over their first. Whiting's annotation reads, "Metal objects taken in a wooden box. The second picture taken just after newspaper accounts of xray discovery." Whiting and Chase then conducted a third experiment, this time exposing blocks of different materials, including glass, quartz, gum, alum, spar, and salt, to assess their relative transparency to x rays. The different materials made it difficult to determine exposure time; the image showed little variation between the blocks, and Whiting noted on the reverse: "A bad print."

Whiting's annotations demonstrate that she was keen to keep track of and perfect her experiments. She used the knowledge gained from the first three attempts to make additional images. In a number of them she used laboratory objects, such as screwdrivers, placed inside containers that seemed to miraculously disappear when exposed to radiation. In one case, she used an assortment of metal jewelry (see figure 4), presumably her own or that of her colleagues, a striking contrast to the objects her male counterparts employed. Other images featured a pince-nez and a round pincushion filled with pins (see the opening image), tools, and hands with and without rings.

Whiting's legacy

Whiting's achievement was celebrated in newspaper articles in Boston and beyond alongside the work of her male colleagues.

FIGURE 4. WHITING'S X-RAY PHOTOGRAPH OF OBJECTS IN A LEATHER POUCH. Most of Whiting's experiments used objects common to physics laboratories or even the average desk drawer. In this example, however, she used a group of decidedly female accessories—a ring, a brooch, a heart-shaped pendant on a chain, and an intricately fashioned link necklace or bracelet—and a tiny key. (Courtesy of Wellesley College.)



But some commentators could not resist referring to her gender in patronizing terms. On 16 February, the *Boston Daily Globe* quoted an unidentified professor as saying, “Perhaps the women at Wellesley will discover an entirely new kind of ray—a feminine ray, or something like that. Or they may find that the Roentgen ray is composed of two parts, male and female. Although no great scientific discoveries have ever been made by a woman, it does not follow that none will ever be, and every student of science is glad to see the women interested.”

But Whiting knew what her x-ray experiments meant for women’s education. In the 11 February *Advertiser* article, she stated that “the colleges for women are quite as much interested and as intelligent in the matter as those for men.” Accounts in Boston area newspapers, and in the *New York Tribune*, indicate that she delivered several lectures about x rays on the Wellesley campus in February, March, and April.

Like other Wellesley faculty, Whiting was active in Boston’s intersecting circles of women intellectuals, writers, artists, abolitionists, suffragists, and reformers. Her work with Röntgen’s rays made her a celebrity among those women. Letters in the Wellesley College Archives indicate that the reformer Mary Livermore invited Whiting to speak to Boston’s Fortnightly Club, a group of women engaged in social justice issues who regularly gathered for lectures on various topics. On 14 March, the Fortnightly Club’s newspaper, *The Woman’s Column*, reported on the great success of the lecture: “The rooms were crowded to hear Prof. Whiting, of Wellesley, on the ‘Photography of the Invisible’ (Roentgen’s Rays). Many were unable even to get standing room.”

Whiting’s x-ray experiments immediately became part of the physics curriculum taught by Wellesley faculty. While Whiting was on sabbatical during the 1896–97 academic year, her replacement taught the topic; in her notes, now in the Wellesley College Archives, Florence Crofut, class of 1897, included multiple references to “Röntgen rays.” Years later Lucy Wilson, a 1909 graduate who in 1945 became the first holder of Wellesley’s Sarah Frances Whiting Professorship of Physics, remembered that Whiting “gave two of us a never-forgotten experience when she provided the apparatus by which we repeated Roentgen’s discovery of X rays. The equipment we used was exactly like that described by Roentgen . . . and we obtained clear photographs of the shadows of our own bones.”¹⁶

Whiting looked back fondly on the collective female effort that went into her experiments. In a Christmas card to Cannon, written sometime between 1914 and 1926, Whiting inscribed a series of reminiscences about her relationship with her former student, including a reference to their work with x rays.¹⁷ Cannon must have felt the same; in her 4 November 1927 obituary for Whiting in *Science*, she commented, “The advanced students in physics of those days will always remember the zeal with which Miss Whiting immediately set up an old Crookes’ tube and the delight when she actually obtained some of the very first photographs taken in this country of coins within a purse and bones within the flesh.”

Whiting retired in 1916, though she remained engaged with life at Wellesley until her death in 1927. Although her x-ray experiments were cited in Cannon’s obituaries and in some modern scholarship, the details and the photographic evidence have

ON THE WEB:
PHOTO GALLERY OF
Whiting’s x rays
VISIT
physicstoday.org/Whiting

not been published before. As almost certainly the first successful x-ray experiments in an undergraduate college, they were made possible by Whiting’s dedication to the laboratory method of instruction and her awareness of advances in scientific knowledge. As the first such experiments by female faculty and students, they exemplify the role of both Whiting and Wellesley at the forefront of the teaching of science,

and the dissemination of knowledge more broadly, to women in the US. It was a legacy that extended to Whiting’s students, who in addition to Cannon, Davis, and Wilson include Isabelle Stone, class of 1890, the first American woman to earn a PhD in physics, and Louise Sherwood McDowell, class of 1898, the first American woman to work at the National Bureau of Standards, now NIST. From her laboratories at Wellesley College, Whiting helped to shape the role of women in the sciences for decades to come.

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