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MAKING SCIENCE VISIBLE: THE PHOTOGRAPHY OF BERENICE ABBOTT

"People say they have to express their emotions. I'm sick of that. Photography doesn't teach you how to express your emotions; it teaches you how to see."
Berenice Abbott, *Art News*, January 1981

"I wanted to combine science and photography in a sensible, unemotional way. Some people's ideas of scientific photography is just arty design, something pretty. That was not the idea. The idea was to interpret science sensibly, with good proportion, good balance and good lighting, so we could understand it."
Berenice Abbott, *Photographers on Photography: A Critical Anthology*, 1966

I encountered Berenice Abbott's photographs in person when I was preparing to teach a course on the intersection of art and science. I was standing in front of the archival cabinets in what was then known as the University of Virginia Art Museum, now the Fralin Museum of Art. New to the collections, I was eager to see what might be available in the way of work showing the relationship between art and science that I could connect to the interests of engineering students in my STS course. What struck me most immediately was how familiar the images were: the iron filings that concentrically spread out around the magnet points and the refraction of light through a prism were images I had seen before in textbooks. Perhaps not with the sharpness, clarity, and elegance of Abbott's images but certainly with similar intent and photographic design.[1] It seemed to

3.1 Installation view of *Making Science Visible: The Photography of Berenice Abbott* at the Fralin Museum of Art at the University of Virginia. 2012. *Source:* Photograph by Hiram Harmon Rogers.

me that these images might have had considerable influence on many other scientific images in very different formats and contexts, and I set about learning more about their maker's efforts in working with science. As it turned out, I would soon be embarking on a multiyear research and curatorial project with Worthy Martin, University of Virginia Associate Professor of Computer Science and Director of the Institute for Advanced Technology in the Humanities, *Making Science Visible: The Photography of Berenice Abbott*, to explore artistic and scientific dimensions of Abbott's photographs (figure 3.1).

Nicole Wade, then the museum's assistant registrar, had invited me to view a group of images from the permanent collection. She arranged four large-format photos across a large stand. Lit to capture the highest possible contrast, they depicted magnets with filings arranged over them, showing the capacity and effects of their magnetic fields. Demonstrative and illustrative of the concept of magnetism, the photos literalized the relationship between art and science. I would later learn that Abbott believed that photography was a bridge between art and science. She wrote that it was "the medium preeminently qualified to unite art with science. Photography was born in the years which ushered in the scientific age, an offspring of both science and art" (1959). Abbott's material and rhetorical moves positioned her work to access a reality that made her work fit into scientific programs. The long artistic career of this American photographer is distinguished by its range of subjects and diversity of collaborators from a variety of fields. In her younger years, she worked with some of the foremost artists of her era, including Man Ray in his Paris portrait studio in the early 1920s, and as a lead photographer for the federally funded documentary *Changing New York* (1935–1939). In the latter part of her career, she worked with cutting edge scientists, particularly physicists, at MIT through the early 1950s.

Abbott considered science to be a photographic subject as early as 1939, when she sought commercial image-making work with industry giants such as IBM and Standard Oil. Abbott would eventually become the photography editor of *Science Illustrated* in 1944, and she continued to work with the publication into the 1960s. In the post-Sputnik era, she would go on to create important images for the National Science Foundation's Physical Science Study Committee (PSSC) in a distinctive modernist style (1956). Her images of gravity, demonstrated by balls being dropped and shot using a stop-motion technique developed by electrical engineer Harold "Doc" Edgerton, a colleague at MIT, was the cover of *The Attractive Universe*, which she co-authored with Evan Valens in 1969. Versions of her gravity photographs continue to be familiar to science textbook readers. Abbott's efforts in scientific image making required revising her own self-construction as an artist. As part of her acceptance into a scientific network, Abbott made clear her intentions to increase public access to science through photography.

METHOD

My methods for this research followed curatorial practices, which place me in a position of participant-observer: as much as I considered the way in which Abbott positioned herself in terms of the field of science and art, in some small ways I also contributed to the way in which she was situated through the production of the *Making Science Visible* exhibition. I used curatorial methods that are frequently employed in museums on both the art and science side that are a hybrid of historical analysis, biographical and period research, and image interpretation (von Bismarck 2021; von Bismarck and Meyer-Krahmer 2020; George 2015). The central item that stands out most is how often ideas of what STS scholars would recognize as interpretive flexibility are at the fore. The concept of interpretive flexibility (Pinch and Bjiker, 1984), or the tendency of users to interpret and use technology in ways other than its creators intended, would be recognized by curators. The shared word root *techne* in art and technology would be one place to start in teasing out these connections. Another point of departure would the use Pinch and Bjiker make of the concept of "artefact," though surely the most salient point is simply that the practice and results of the analysis are to the same end: to understand how others have understood the same object.[2]

Curators would hardly recognize the terminology of STS methods (and vice versa), but they would surely recognize the practices themselves. Many curatorial methods function as critical inquiry by bringing a history of interpretive flexibility when different curators and institutions have understood objects differently and have made efforts to reiterate them in new contexts to produce or highlight specific possible meanings. The curator does her best to review these uses and in doing so develops an account of the moments of interpretive flexibility around the object before engaging in this practice herself. My research on Abbott began with a review of the textbooks to which she contributed, then moved on to a survey of her science images. Eventually, this led me to research Abbott's life in preparation to curate an exhibition (*Making Science Visible: The Photography of Berenice Abbott*) of her work for the University of Virginia's Fralin Museum of Art. I employed a number of curatorial methods in this portion of the research, including considering her photographs in the various science, documentary, and art contexts in which they appeared; the uses to which curators had placed her photographs; and the arguments made by placing her images alongside the work of other photographers. Most often, this had been done in the context of historical retrospectives on the Federal Art Project (1935–1939), part of the Works Progress Administration, or more generally in the context of

Depression-era artists. These methods are informed not only by exhibition publications and museum exhibition records but also by the visual materials themselves. because the goal of such research is, in the end, to mount the images in a way that allows viewers to see them anew and to take away a more nuanced understanding of Abbott's work. This places the curator in a position akin to that of the artist or scientist: to use materials, albeit aided by textual rhetoric, to make an argument.

Through the development of the exhibition, I spoke to scholars who had written about Abbott and to education scholars about Abbott's contributions to pedagogical images. The exhibition *Berenice Abbott: Photography and Science: An Essential Unity* appeared at the MIT Museum in the same year, and I benefited from conversations with Ron Kurtz and from his excellent catalog *Berenice Abbott: Documenting Science* (2012).

Curators are knowledge makers. The overlap that some curatorial methods have with STS practices, particularly by way of the attention to what STS scholars call *interpretive flexibility* and what curators see as a basic idea fundamental to their practice, should encourage ASTS scholars to consider the ways in which these practices may be particularly fruitful in engaging with materials at the intersection of art and science.

LEARNING TO SEE

At the time I saw Abbott's photographs at the University of Virginia, I was familiar only with Abbott's influence on documentary practice and her work with cityscapes and rural laborers. I had grown accustomed to asking my students to look carefully at eighteenth-century drawings of animals discovered during Europe's colonial expeditions to understanding secondary observation and the role of texts as guides for rendering images. I asked them to consider the pedagogical value and celebration of science and mathematics contained in German Renaissance printmaker Albrecht Dürer's *Melencolia I* (1514) to understand how this homage to Enlightenment values functions through its combination of mathematical and religious symbols.

In contrast, Abbott's work intuitively seems more familiar to the viewer. That is not surprising, because her images were widely used by scientists to teach science. Whether we consciously remember it or not, many of us have encountered this style in one form or another. Yet active aesthetic choices of the image maker can be more easily hidden by our contemporary assessment of the "correctness" of the image. Our belief in the particular scientific principles and details contained in the image can give the depiction an aura of objectivity, obscuring the work that artists put into creating the images.

This apparent simplicity belied the stagecraft necessary to produce such a realism. Abbott's success in these images was that they captured the subject so completely that they hid her own artistic labor. Having used the rather obvious "errors" of colonial painters as a shortcut to showing students how aesthetics and historical science functioned as intertwined knowledge, Abbott's science images offered a new set of interpretive problems. Abbott aligned her material practice of photography with a rhetorical practice of defending realism as the proper use of the camera. Reconciling historical understanding of science with historical understanding of representation provides an entryway to understanding how science was constructed in this context. In my role as an educator, then, I sought to position Abbott's work as contributive to science, claiming a special role for her photographic practice in that process in the context of the power dynamics between art and science. The question was how to teach my students to "see" these dynamics. Promising more Abbott images on my next visit, Wade smoothed the edges of the archival tissue over the images, and they disappeared into the cabinet of photographs.

Learning how and what to see is a central skill in science. In this sense, practice trains the eye. What we see is, in fact, a perspective, and therefore changeable. The skill of seeing and knowing how to look are fundamental to creating expertise in science. As Abbott expressed earlier, the right use of tools is required for proper seeing (Lynch 1988). Like the Blaschkas, Abbott used what she called a realist style, one commensurate with the needs of scientists. Unlike the glassmaking team, however, Abbott employed realism in the service of popularizing science for the public good. Her goal of offering accessible images of the science of everyday life, distinct from the agendas of the scientists for whom she worked, aligns her with the tactical media practitioners of the 1990s and 2000s that we will encounter in Chapter 4.

Abbott's ideas about what photography could do to educate the public by casting social issues in a new light are well documented in studies of her photographs. How this impulse was extended and took shape in her science photographs has received less scholarly attention, giving rise to a sense that Abbott has created separate bodies of images. Although these early and late images do show some distinctions, treating them as entirely separate spheres obscures Abbott's interests in both projects. This in turn has informed interpretations of her science work solely in terms of photography in the service of science.

A more holistic consideration of Abbott's work would address her realist aesthetic and philosophy of what camera technology could offer her viewers, a group she conceived of as a polity in need of a science interpreter. In contrast to tactical media, Abbott embraced technology as an instrument that could service science, a relationship she believed enabled the camera to realize its maximum potential. Her science images offer art historians a chance to see the body of Abbott's work afresh and to consider the contributions of artists to scientific knowledge communities.

The images also lend insight to the effects of rationalist thinking on artistic practice. Abbott was often at odds with artists whose pictorial approach she defined as being in opposition to her own work. To her, human vision was flawed; only the camera could lay bare the facts. As she put it, "What the human eye observes causally and incuriously, the eye of the camera notes with relentless fidelity." This belief is familiar to readers of Daston and Galison (2007): The photograph, which was the essence and emblem of mechanical objectivity, carried no metaphysical cachet; at best it was an accurate rendering of sensory appearances, which are notoriously bad guides to the "really real." It also would not have passed muster with aperspectival objectivity, which eradicates all that is personal, idiosyncratic, and perspectival. The photographic "look" was in fact radically perspectival—as many of our X-ray users never ceased to lament. We can fully understand why photographs wear the halo of objectivity only when we recognize that the kind of objectivity that beatifies them is mechanical objectivity, and not its metaphysical or aperspectival kin.

None of this should detract from Abbott's contributions to science. Even as she upheld the camera as having ostensibly objective properties, she problematized this position by suggesting that it was possible to use the instrument in ways that were *not* true to its nature. To be sure, Abbott regarded such applications as error. She opposed the use of the camera to mimic older forms of artwork, arguing instead for a type of photography that avoided the conventions of painting, a position that would alienate her from the American photographic establishment. The camera could surpass those forms only if it was not misdirected, particularly through technical interventions in film development. To merit serious consideration, Abbott insisted, photography "must be directly connected with the world we live in."

Yet achieving fidelity took craft. Unlike art photography of the time, Abbott's brand of photorealism required elaborate staging to avoid having to tamper with the image in the development stage. Her earlier schooling in the artistry of photography would prove a crucial element in her ability to use the camera to capture scientific truths.

EARLY YEARS

Abbott was born in Ohio in 1898 and was the youngest of four children born to Lillian Alice Bunn. After two semesters at Ohio State University, she initially planned a move to New York to study journalism at Columbia University. In 1918, she moved to Greenwich Village, where she met artists, poets, and political activists. She trained independently in New York as a sculptor, published experimental poetry, and met avant-garde leaders Marcel Duchamp and, most important, Man Ray, who would soon move to Paris. In 1921, Abbott left New York for Europe, traveling first to Paris and Berlin before settling in Paris. In France, she became Man Ray's photographic assistant when he arrived about a year after her transatlantic move. The move would eventually lead Abbott to shift from image processing to image making. She had her first solo show at the gallery Le Sacre du Printemps in Paris in 1926, which included a number of portraits such as her classic image *James Joyce, Paris*. There, she met Eugène Atget about two years before his death. Hearing that he had passed away, she sought out his photographs and worked to raise his profile. Atget had been an artist's photographer who created images, mostly of Paris, for study by artists who often made use of his viewpoints. She worked to create interest in Atget's contributions to the art world and was credited with solidifying Atget's legacy by reproducing his work from negatives. In 1929, Abbott returned to New York, where she was impressed with the building scape that had developed in the postwar boom years. She made important photographs of the city just before the start of the Great Depression. As this economic event set in, she found employment directing the social documentary *Changing New York* for the Federal Art Project, receiving a salary and assistance (Massachusetts Institute of Technology 2012).

Abbott focused her camera on the built space of the city itself. Some of the most celebrated images are of iconic buildings and skyscrapers, evincing an interest in the advanced technology of the time. In a documentary on her work and life (*Berenice Abbott: A View of the Twentieth Century*, 1993), Abbott explained her interest in urban environments as flowing from her belief that "the city expresses people better than people express people." In this sense, the project continued her work in portraiture, only this time the portrait would not be of an esteemed artist but of society as expressed in its monumental works of infrastructure. Elizabeth McCausland (1899–1965), the art historian and social critic and Abbott's lifelong partner, wrote the text for the project, and her critiques of art coincided with Abbott's ideas about new aesthetic development turning away from representing reality (University of Chicago 1966; McCausland 1973). In a 1938 pitch to her editor, Abbott wrote, "I want my book [. . .] to reach a new audience, not the audience of scholars, connoisseurs or museum directors, but the audience of simple American millions, without whose support and intelligent understanding America cannot hope to produce a vital and democratic art."

Abbott had a critical view of abstract painting despite a close friendship with Arthur Dove, often considered America's first abstract painter. This shared philosophy of art in the public interest bound Abbott and McCausland to social realism, ideas they further developed over the course of *Changing New York*. Together, they completed this ambitious venture in 1939. In all, Abbott worked on her vision for six years before being hired by the Federal Art Project. She completed the project four years later, having worked for a decade to produce the documentary (Abbott et al., 2012;

Ware 2004, 2–3; Sullivan 2006, 122; Weaver 2013). In 1944, Abbott was one of the first members of the American Society of Media Photographers (ASMP), a union primarily of visual communicators and commercial photographers. In a 1990 interview with the organization, she described her motives for joining as stemming from her treatment when she worked for IBM photographing computers: “I joined ASMP because I believed in unions for people, and photographers were having a terrible time. IBM, for instance. They wanted some work done on their computers, and an ordinary photographer couldn’t have done it. So they hired me. But they wouldn’t give any extra money. We really got the dirty end of it.” One of Abbott’s photographs shows a woman working on an IBM calculating machine.

As early as April 1939, Abbott was articulating her reasons for focusing on science images. By 1944, she had become the photographic editor of the general audience science magazine *Science Illustrated*, a publication that survived only until 1945, when McGraw-Hill purchased it. Abbott scholar Terri Weissman has argued that this was a stroke of luck, a turning point in Abbott’s shift toward science imagery (2011). At *Science Illustrated*, Abbott ran photographs that the contemporary eye might well have found feminist in their insistence on representing women and domesticity in explaining scientific phenomena. For example, Abbott’s image of static electricity centers on a woman with a hairbrush, which connects the everyday activity of grooming with the science of electricity through the concept of static transfer to the hair.

However much of Abbott’s photography was influenced by her new science subjects, many of the skills crucial to the creation of the pictures that would appear in *Physics* had been honed in previous pursuits. In his introduction to *Berenice Abbott: American Photographer*, art historian and critic John Canaday likened Abbott’s preparations for her ideal picture to capturing a scientific specimen. For Canaday, it was “almost as if a trap had been set” (O’Neal 1982). For her famed photograph *New York at Night*, she explained:

> I took this early in the evening. There was only one time of the year to take it, shortly before Christmas. I started about 4:30 PM and didn’t have much time. But I had done a good deal of prior planning on the photograph, going so far as to devise a special soft developer for the negative. This was a fifteen-minute

exposure and I'm surprised the negative is as sharp as it is because these buildings do sway a bit. I knew I had no opportunity to make multiple exposures because the lights would start to go out shortly after 5:00 PM when the people began to go home and so it had to be correct on the first try.

At sunset on December 20, 1934, Abbott's preparation paid off when she captured this iconic image of New York. Abbott was quick to reference her artistic roots even when creating explicitly scientific images. In describing the inspiration and technique for creating her wave pattern series on light-sensitive paper, she credited the Bauhaus professor and Hungarian painter/photographer Moholy-Nagy and her employer, Man Ray, both of whom made priority claims on the 1922 invention of the photogram, creating an image using light-sensitive paper but without the aid of a camera. "My idea," she explained, "was to do a rayogram in motion. Moholy-Nagy and Man Ray had done pictures by putting objects on sensitized paper but I wanted to do the same thing in motion."[3]

For Abbott, this kind of image making, like photography itself, had roots in both art and science practice. These intertwined strands made photography well suited to her purposes. It was the proper way, she felt, of bringing the public into scientific conversations. In her manifesto on photography and science, she wrote that "we live in a world made by science . . . There needs to be a friendly interpreter between science and the layman. I believe photography can be this spokesman, as no other form of expression can be."

Abbott's goals for her scientific projects aligned aesthetically and intellectually with her previous documentary projects in that they called for the employment of realism, with the aim of helping the public understand the world. Abbott's realism was further defined by the consciousness of her social documentaries and her discursive and pedagogical science rooted in her approach to photography. As outlined in two influential essays, "Straight Photography" and "Documentary Photography" (Abbott 1941), this philosophy derived from her subjects. Unlike her social documentary, however, Abbot's science images were meant not to inculcate critical reflection on science as a social process but rather to assist in the interpretation of reductive science. If we understand Abbott's work as representative, this would align her with a large swath of work that is today sometimes referred to as "sci-art."

BIG SCIENCE, BIG ART

As a photographer and editor for *Science Illustrated*, Abbott frequently engaged with scientists. It was not until 1958, however, that Abbott would be paid to create science images. The catalyst was the Sputnik crisis, and once again Abbott found employment with the government. She was hired by the PSSC, set up in 1956 by MIT scientists to investigate and revise the physics curricula across the United States, particularly at the high school level. Supported by the fledgling National Science Foundation, the PSSC had among its charges the development of teaching aids, especially film and visual materials, and among its major projects was a textbook. Entitled *Physics*, the text was designed to encourage excitement and interest in the subject rather than emphasizing memorization (Abbott et al., 2012).

Abbott's role was to create photographs for *Physics*. Her photographic experiments at PSSC would yield iconic images that influenced both informal and formal science education. Her style of preparing the conditions for photography, rather than creating alterations in the darkroom, required assemblage of precision apparatus and exacting techniques. As such, her work was not dissimilar from that of the scientists who populated nearby laboratory spaces at MIT. Abbott invented what she needed as she worked, developing cameras and equipment such as specialized tripods as well as techniques suitable to individual subjects. Her standards and requirements for complex materials, which sometimes involved an individual build for a single shot, might be thought of as a kind of "big art," a parallel to the "big science" with which she was colocated.

With the advent of the space race, and science now a matter of national security, science communication was suddenly important. In the wake of the shock resulting from the Sputnik launch, Abbott thought, "now people might think a little differently." The hope that a change in public attitudes and financing might make possible her photographic studies of science spoke to her belief that current events were both the impetus for and the raison d'être of her efforts. It also related to Abbott's livelihood as a working photographer, however. As the child of a divorced mother, Abbott had limited means, so her production of large-scale artistic projects is all the more remarkable. She was a working artist throughout her life. She taught art and photography, published books on photography, began a commercial gallery, and patented a number of photographic tools. Like many artists, Abbott was also an inventor and held a number of patents for photography-related designs. She attempted to develop and market these innovations through a short-lived corporation she founded in 1947 called The House of Photography. Tools she developed including the lighting pole, now known as the *autopole*; a 20-pocket coat designed to hold everything that the photographer on the move could need; and the Abbott Distorter, which she used to create a self-portrait that shows a recognizable Abbott with oversized eyes looking directly into the camera.

Even before founding the company, Abbott devised a new type of camera called the super-sight (O'Neal 1982).[4] The supersight camera was particularly helpful in capturing the enlarged details often needed for her scientific images. This unwieldy camera was the opposite of a camera obscura: objects were placed inside it to be photographed (Sullivan 2006). In a camera obscura, the world passes through a tiny slit and is projected (to be traced either on paper or onto film). Abbott's supersight camera works in precisely the opposite way: a small field comes through the camera and is projected as a very large image directly onto film, producing a detailed, grain-free image.

Critics might view Abbott's interest in science as a means to produce a steady stream of income to allow her the freedom to work on projects more closely associated with art. This, however, requires us to ignore both the many years that it took Abbott to find positions in science and the way that she describes her science work as a public service. During this period, her artistic training was brought to bear in a number of ways, and, in a telling commentary of her commitment, Abbott did not take on any other large-scale projects. During her time at MIT, Abbott produced a number of photographs and photographic techniques for displaying concepts such as gravity, light, and magnetic fields, which are not usually included in discussions of her artistic contributions despite their continuing influence on how these ideas are imagined and on pedagogical scientific illustrations.

Though credited as an individual on many of her science photographs, Abbott is not remembered primarily as a science photographer in art history. Her photographs have also not elevated her to any considerable status in the science community. Abbott's status in relationship to her photographs and her relative standing in art and science may be amplified by the norms of art and science or through an interaction effect, in which she understood the practices of each group and positioned herself accordingly. So complete is the anonymizing of her work in science that she is not identified with the stop-motion images of balls that she created to depict gravity. This is perhaps more a reflection of the status of image makers in science than the identification of the photographer in art. This separation is possibly evidence of Abbott's ability to position herself. So convincingly did she situate herself first as a portrait photographer, then as a documentarian, and finally as a science imagemaker that scholars of her work have tended to separate those bodies of photographs into separate careers (Weissman 2011).

Creating ways of seeing art and science work across a single individual's career surely enhances our knowledge of the person and their respective pursuits. Among those images assigned to the science part of her career is Abbott's often duplicated and reproduced photograph of a bouncing ball that was used to depict gravity, which appeared on the cover of *Physics*. It was produced using flashing lights during her work with Harold Edgerton (Massachusetts Institute of Technology 2012). Edgerton was an electrical engineer at MIT who was working with strobe lights and photography to capture stills of fast motion in physics. He maintained a lifelong association with photographer Gjon Mili of *Life* magazine, a venue where Edgerton published many of his photographs. In 1957, Edgerton created the *Milk Drop Coronet*, which uses his revolutionary stop-motion photography techniques. Though they are sometimes described as having very different backgrounds (Abbott from the art-side and Edgerton from the science-side), Abbott and Edgeton both worked with techniques related to an object's motion through photograph with a focus on capture the moment in front of the camera lens by manipulating light, rather than suggesting motion through darkroom techniques. Both photographers became well-known for their contributions to the physical sciences understanding of objects positions in cases where the movement was beyond the comprehension of the human eye alone. Abbott's falling wrenches in her photograph *An Asymmetrical Object Behaves Symmetrically* (1958–1961), that illustrated a scientific principle. The wrenches demonstrate the law of averages, with a single center point in the wrench staying in the same place as the object falls.

One of the most interesting aspects of Abbott's work in this period was her recognition of the collaborative nature of science practice. The gravity photos, for example, had required large teams and careful coordination of the dropping object, camera, and lighting. Abbott remained committed to showing what was in front of the lens and avoiding darkroom corrections to the extent possible. In this way, she seemed relatively less interested in the staged "subjective" world behind the lens. Nevertheless, the convivial nature of collaborative big photography agreed with Abbott, and she referred to this period as "the happiest years of my life" (Abbott and Mitchell 1979). This time ended, she recounts in *Berenice Abbott: A View of the Twentieth Century* (1993), when her job was given to a younger man whom she had trained. Abbott remarked, "the world doesn't like independent women, why, I don't know, but I don't care." She would soon relocate to Monson, Maine, where she would work on her labor and place photographs.

SCIENCE OF THE EVERYDAY

Among the contexts that Abbott's images spoke to was the science of everyday experience. A good example is *Soap Bubbles* (1945), reproduced in *Science Illustrated* in July 1946 to illustrate an article explaining the chemistry and mechanics of soap. It discusses washing and featured a companion piece on synthetic fabrics, suggesting that the publication hoped to reach beyond the boys and young men typically targeted by the popular science media. In *Soap Bubbles*, Abbot illustrated the geometry of soap froth, explained in the accompanying text as the consequence of molecular differences between hard and soft water.[5] Using her supersight camera (Abbott et al., 2012), Abbott had to conduct repeated experiments with types of soap to capture this image, one of her most frequently reproduced and copied. Through such quotidian science communication, Abbott hoped that the public would be increasingly interested in supporting scientific inquiry.[6]

Abbott also worked with prosaic biological subjects, though even in these relatively simpler images she sought to suggest the relationships between subjects. For the science textbook *American High School Biology*, Abbott photographed a Japanese beetle (*Popillia japonica*). The insect had turned a leaf into a latticework of veins. This text (Grant, Cady, and Neal, 1948) took the unusual step of visibly crediting Abbott with each photograph as "Miss Berenice Abbott." It introduced early ideas about ecology for classroom readers. Individual organisms are pictured with other organisms, and their relationships are the focus of the text. Of particular interest are agricultural "pests" pictured with the plants that they consume. Rather than showing insects in isolation, Abbott encouraged viewers to think of the effects of the Japanese beetle in an ecological context. In this staged image, the background is the leftovers of a leaf meal, complementing the text's points about the relationship between these two organisms.

The contrast in this image's relational aspects is made starker when compared to Abbott's large-format *Untitled* image of the giant water bug *Lethocerus*. The specimen is on its back with no special background so viewers are encouraged to note the sections of the body and the articulation of the insect's legs. Images in science textbooks need to be constructed both to fit into current scientific culture and to demonstrate specific features that scientists are trying to convey. The problem for the photographer, then, is how to encourage the viewer to notice those aspects of the image that match scientific purposes. In this photo, Abbott has removed all context through careful lighting, which minimizes the visibility of any shadows cast by the subject. The framing and orientation give the strong impression that the insect is large. Abbott's exaggerated framing lacks the pedagogical aims and context of the textbook image, the contrast serving to underscore the artist's contribution to new ways of creating images to understand biology.

In explaining her motivations, Abbott put herself in the position of the viewer requiring scientific interpretation: "The idea was to interpret science sensibly, with good proportion, good balance, and good lighting, so we could understand it." Taken in conjunction with her claims for the camera's "relentless fidelity," her explanation of the ideal popular science photograph demonstrates the tension between the role of the artist in making choices and what Abbott believed was the objective use of camera technology. For Abbott, the trick was to render her craft invisible to viewers to create a photo that appeared to expose the facts of science while preserving its aesthetics: "The scientific photographs had to be carefully composed, but they couldn't look that way. I didn't want the composition to be so obvious as to take over . . . when you look at a photograph and all you can see is the composition then you know it is a big flop" (O'Neal 1982).

Many photographers and other scientific image makers are heirs of the ideas for science photography and even the image style that Abbott proposed. One example is Abbott's concept of a photo that acts as an illustration. Prisms are familiar subjects for optics photographs, but in Abbott's *Light Through Prism*, viewers encounter a different kind of prism made to show refraction and reflection. In this photo, viewers see Abbott's setup from the top. She describes arranging two glass triangles with water between them, being sure to avoid creating air bubbles, and held together by cohesive force. The separate beams of light enter the prism at a variety of angles. In the first three beams, viewers can actually see refraction displacing the light slightly, the way a bent straw in water would look. By the time we reach the latter three beams, however, the angle of their entry causes the beams to reflect off the right triangle wall, crossing through the upper part of the triangle. The beams are reinforced as they cross, so spots of brighter light are produced. Abbott explained that creating this effect took thoughtful staging: "Multiple beams of light from a source change direction when they go into a glass plate and when they emerge. Some waves are reflected inside the glass and then escape. The prism photograph was done very carefully. The prism was filled with water and not one drop of air was inside. The box that held the light source was specially designed and purposely looks as it does to make for a better composition" (O'Neal 1982).

This careful composition was necessary to the two natures of lights that Abbott was attempting to illustrate. She reminds us of the particle and wave nature of light beams by producing an image that shows the beams of light as being smooth when inside the prism but discrete when outside it (Weissman, 2011). Weissman proposed the term *photodiagrams* to describe these illustrations through photographs, which do not show the phenomenon itself but rather purport to offer a way to understand it. For Abbott, these images are not simply attractive designs abstracted from phenomena but proof and demonstration of science ideas through photography.

SCIENCE, DEMOCRACY, AND THE REALIST IMPERATIVE

Artists and image makers are typically considered to be outside science, even when their contributions enable instrument design and data visualization as well as science communication and critique (Weissman, 2011; Kurtz 2012). Abbott's experience is a corrective to this view. By the early 1960s, the PSSC had enlisted nearly 20 percent of US high school physics teachers into its efforts and was a major force in reshaping physics curricula worldwide (Daeschner 1965). Abbott's images for this project do more than document a historical moment in science. They materially contribute to pedagogical practice and, in particular, the expansion of visual practices at a particular moment in science history. They do not just illustrate or draw attention to science. The visual language of these photographs helps us experience and observe scientific processes, from the consequences of the laws of physics to contrasting visions of the biological world.

Abbott's realist impulse aligns with her goals for democratizing science. We can readily see how her rhetoric supports the idea that her photographs would represent a reality in which viewers could observe the workings of scientific phenomena. Abbot understood that her realist aspirations for photography contrasted with the efforts of her peers such as Alfred Stieglitz, whose work she described as "art . . . by the few for the few." In *A Guide to Better Photography* (1941), Abbott critiqued the pictorialists. She believed that what was in front of the camera was of secondary importance for these artists, who selected subjects primarily to showcase and experiment with photographic processes.

Abbott also took issue with what she saw as a display of darkroom techniques over subject matter. For her, "photography is for communicating the realities of life." In an address for the Aspen Institute Conference on Photography in 1951, Abbott stated the following:

> . . . this medium of photography is so young that it is not fully understood by experts or by photographers. The greatest influence obscuring the field has been pictorialism. At this point it may be appropriate to define pictorialism.

My definition would be something like this: that pictorialism means chiefly the making of pleasant pretty pictures in the spirit of certain minor painters. What is more, the imitators of painting imitate the superficial qualities of painting, are not themselves aware of the true values for which painting strives. The only relationship is that of a two-dimensional image on a flat surface within a certain area, but the natures of those two images are worlds apart. Photography can never grow up and stand on its own two feet if it imitates primarily some other medium. It has to walk alone. It has to be itself.

Abbott may have sought the truth available only through photography. The material of her photographs aligns with the aims of her rhetoric. A clear vision of what was in front of the camera was necessary to her sense of the realist purpose of photography as well as to her sense that the public needed photography as a bridge into "the world made by science." She believed that though the camera might be directed to produce images in a style evocative of earlier artistic media such as painting, the proper use of the camera was to avoid duplicating old styles. For Abbott, the best use of the camera was to render detail faithfully and thereby to reflect what she saw as realism. Her photographs and her descriptions of them defend an objective reality at odds with many of her photographic peers and in conflict with Daston and Galison's critique of the camera as an attempt at mechanical objectivity (2007).

However simplistic Abbott's motives may now appear to us, the influence of her photographs on how science was imagined by readers of *Science Illustrated* and *Physics* should not be underestimated. In her images, Abbott and many of her viewers saw what they believed to be an objective reality, devoid of postexposure tampering and visualizing what hitherto had been unseen. Abbott's wish to show only what was before the camera, coupled with her desire to educate the public about science, produced ironic dual images: photodiagrams that were at once illustrations of unseen scientific phenomena and photographs with a weight beyond illustrative representations taken to be less than objective.

Abbott's penchant for highly staged works also emphasizes her interest in what was in *front* of the camera, rather than darkroom processing techniques. In the case of scientific images, this meant making the ideas of science broadly available. Abbott attempted to communicate, and thereby democratize, what she saw as the power of her time—science—and to encourage engagement with science. To accomplish this, Abbott's images speak to knowledge communities in both art and science. Through her documentary photographs, Abbott is recognized as having contributed in an important way to social purpose through the arts. Abbott's science photographs should be seen in a similar light. For her, these images represented a way for the camera to reach beyond previous artistic media such as pictorial photographs and beyond typical aesthetic subjects into another arena of social progress. Her science legacy includes new ways of understanding what a photograph could add to scientific literacy and developing one potential role for the photographer in science practice.

EXCAVATING ART-SCIENCE

The story of Abbott's work in science can help STS scholars cast into relief the contributions of artists who have seen themselves, or have been seen by others, as serving science. The art community frequently derides such work as lacking ideas or privileging communication content. For its part, the science community celebrates the "useful" qualities of such work but does not recognize it as a contribution to the project of science. Despite being fundamental to the practice of science and crucial to knowledge transfer between scientists, their students, and the broader public, images made for use in science are too frequently pictured as not contributing to the project of scientific knowledge making (Latour 1986; Lynch 1988). On one hand, these artists are seen as the instruments of scientists because the scientist disciplines the artist's work. On the other hand, such artists are seen as not contributing to the world of art because their work is delegated to auxiliary status, craft, or even advertisement. Scientists' limited knowledge of artisanal craft, however, suggests that artists are adding something more than technical work to the scientific process. Such workers range from artists who work as technicians, including sketch artists and photographers who served on exploratory missions (Codling 1997) and inside science labs, to those who, like the Blaschkas, worked for scientific institutions but did not directly collaborate with scientists on a daily basis.

Abbott coupled a role as a science image maker with a distinct philosophy of science in the public interest. This alignment between the interests of artists of this type and scientists tends to mask the artist's agency in producing science work. In later chapters, we will observe artists whose work is at odds with parts of the science community. Like STS scholars who follow failures to understand the practices of science, these mismatches in goals and even direct critiques of science illuminate artists' contributions to the scientific knowledge making and controversies. This does not mean, however, that these contributions are not present in cases where there is philosophical alignment. Though the differences may be subtle, many of the same processes are at work.

Understanding the contributions of artists, even those who did not claim to contribute to science, is just as important to exploring the intersection of art and science as examining the work of artists who critique and contextualize science. Indeed, the role of the STS scholar is to observe what is happening in the social world of science, regardless of what scientists (or artists) say is happening. For the analyst, following the rhetorical moves of actors in concert with their practices is necessary. The STS call to follow the actors may ring especially true in the case of art, because artists who work in science often have an economic stake in not insisting to scientists that they are full participants in the enterprise. In some cases, artists themselves may not always understand their contributions to science. More often, it is likely that economic factors are in play, because scientists have greater access to government and corporate funding, so they are in the position of hiring artists as employees or contractors.

It is not surprising, then, that artists like Abbott rhetorically positioned themselves, perhaps somewhat defensively, as essential to the scientific enterprise. In the documentary film *Berenice Abbott: A View of the Twentieth Century*, Abbott recollected that in her 1958 interview at MIT with Dr. Elbert Little, she argued "that scientists were the worst photographers in the world," but that "they need the best—and I was the one" (Weaver and Wheelock, 1992). Although it may be clear to STS scholars how vital visual representation is central to the practice of science, that point may be less obvious to a scientist or artist.

Scientists have tended to see image and model making as auxiliary to their aims, though Latour (1986) and Lynch and Woolgar (1990) have shown that image making in particular is fundamental to the scientific process. Elsewhere Lynch (1988) has shown the relationship between analytical visual displays and quantification vis-à-vis images. Other

STS scholars, including Elgin (2010), Castel and Sismondo (2002), and Downes (1992), and philosophers of science (Black 1962) have made the case that models, too, are fundamental to scientific understandings. Models and images are more than objects of demonstration or ways to derive theoretical perspectives: to paraphrase Nancy Cartwight, they themselves are a theoretical perspective (1983). With this in mind, close studies of artists' contributions to science appear even more necessary.

Like technicians and others considered outside the scientific enterprise, science-engaged artists are, in fact, understudied science workers. Some efforts have been made to comprehend what scientific images encode beyond their role in the scientific process. Kathryn de Ridder-Vignone (2012) has shown that well known artistic conventions are often enlisted in situating scientific images as part of a perceived artistic discourse. In the case of nanoimages, de Ridder-Vignone's example, received artistic styles like landscapes were harnessed in situating these images as art while also keeping account of their scientific value. Until we come to terms with the multiplicity of skills and persons involved in science, however, including its artistic aspects, our understanding of the social shaping of science will be incomplete. As we have seen in the case of the Blaschkas, aesthetic values are encoded as well, in ways that STS scholars have hitherto found difficult to decipher. Combining STS tools with those of art historians and visual culture scholars may start the process of developing a key.