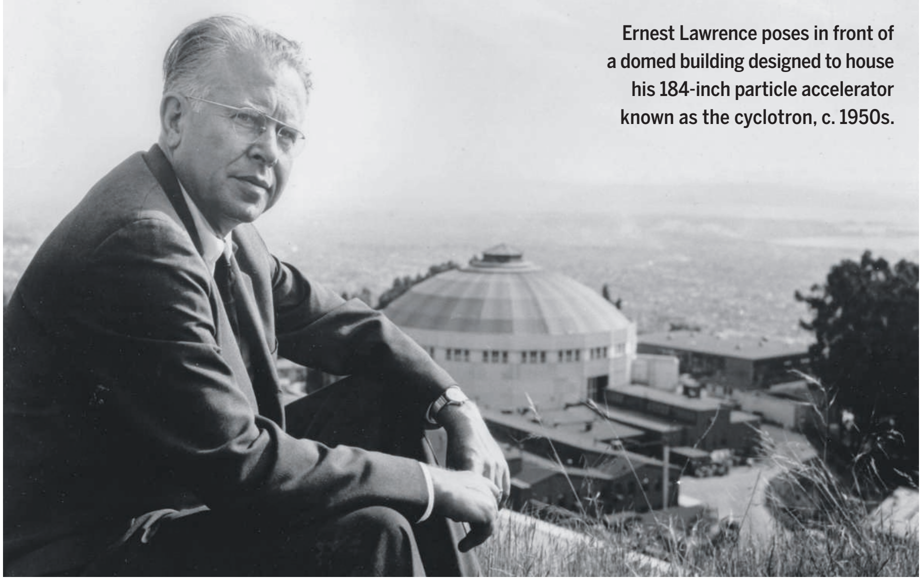

Ernest Lawrence poses in front of a domed building designed to house his 184-inch particle accelerator known as the cyclotron, c. 1950s.

HISTORY OF PHYSICS

Cult of the machine

A major player in 20th-century physics, Ernest Lawrence helped usher in an era of big-budget research projects

By **Alex Wellerstein**

High above the hills of the University of California, Berkeley, sits a physics laboratory that employs more than 3000 people, boasts an association with 13 Nobel Prizes, and has a budget of over $750 million dollars. The Lawrence Berkeley Laboratory is named after its founder, the famed American physicist Ernest Orlando Lawrence. Lawrence's name also adorns the Berkeley laboratory's weapons spinoff at Livermore, a career award issued by the U.S. Department of Energy, and an element (the actinide metal "lawrencium"). By any standard, he was a giant of American physics and, arguably, the architect of the late-20th-century approach to science that required big machines, big budgets, and big staffs, known fittingly as "Big Science" (*1*).

Michael Hiltzik, a Pulitzer Prize–winning journalist, has written a new biography of Lawrence, the only such monograph published since Herbert Childs's (family-sanctioned) book *An American Genius* was released in 1968 (*2*). Hiltzik takes a less hagiographical approach than did Childs, and the book reflects a shift in society's perception of Big Science, in particular its deep historical connections to military research.

What kind of scientist was Ernest Lawrence? He was less a discoverer than an inventor, more a tool builder than a tool user. At the center of Lawrence's world was the circular particle accelerator he invented, dubbed the "cyclotron." Around this initially humble creation, Lawrence built an empire of labor and of funding and a new way of doing physics.

Lawrence's approach relied on the "remorseless exploitation of cheap graduate-student labor," as Hiltzik aptly puts it. His first cyclotron, a small device a mere six inches in diameter, was apparently constructed entirely by a graduate student named Niels Edlefsen. Lawrence was singing its successes even before it was clear that it worked—which, it turned out, it didn't. The first functioning model was developed by his next student, M. Stanley Livingston, who debugged the earlier machine and fixed its numerous faults. Even before Livingston had put the cyclotron prototype through its paces, Lawrence was hot on the trail of the money needed to build a bigger model.

Lawrence's methods were viewed with justifiable skepticism among the scientific greats of Europe. For the first decade, they failed to produce real results. His first major scientific announcement—a theory of deuteron disintegration—proved to be an embarrassing flop. Instead of describing a new phenomenon that overturned the laws of physics, Lawrence instead broadcast to the world that the Radiation Laboratory couldn't keep its samples clean.

Lawrence's problem, as diagnosed by his contemporaries, was that he was more interested in the "cult of the machine" than the scientific results. A French visitor once ridiculed the laboratory for having "a mania for gadgets or a post-infantile fascination for scientific meccano [sic] games." The number of major discoveries that the Radiation Laboratory ought to have stumbled across, had it been watching for them, is a long one: The existence of the positron and the neutron were discovered during this time by using more modest tools and staffs, for example, as were the phenomena of induced radioactivity and nuclear fission.

Yet the funding continued to pour in, in part because of what Lawrence would at one point dub "the vaudeville"—his ability to project boundless enthusiasm and confidence to nonscientific audiences. In a rare moment of candor, he once admitted that he was making the cyclotrons bigger simply because he could get the money to do so, not because he had any idea about what the bigness would let him do.

To a large degree, Lawrence's strategy worked. The cyclotron went from being a crazy venture to a common tool, earning Lawrence the Nobel Prize in 1939. Part of the reason for this was that, in the right hands, it did yield important results. Ed McMillan, Luis Alvarez, and Glenn Seaborg—all future Nobel Laureates—cut their teeth and did some of their best work in the Radiation Laboratory, finding ways to make Lawrence's chaotic fiefdom work for them. Additionally, when it became clear that cyclotrons could produce radioisotopes in quantity for other types of scientific research, Lawrence was happy to provide them to collaborators, knowing that he could only gain from their rising applicability.

The Second World War brought the ultimate patron to Lawrence's door: the U.S. military establishment. Lawrence's involvement in defense work began with radar but hit its stride with nuclear weapons. His relationship with the military would continue until the end of his life.

Big Science
Ernest Lawrence and the Invention That Launched the Military-Industrial Complex
Michael Hiltzik
Simon and Schuster, 2015. 549 pp.

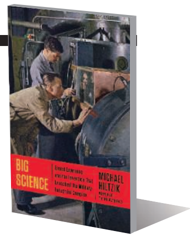

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PHOTO: EMILIO SEGRÈ VISUAL ARCHIVES, AMERICAN INSTITUTE OF PHYSICS

Lawrence was one of the loudest proponents of building the atomic bomb, largely because he claimed that he could practically pull it off single-handedly. In this, as with many things, he overpromised. The results-driven General Leslie Groves, head of the Manhattan Project, who did not accept the kinds of delays, excuses, and cost overruns that Lawrence had become accustomed to, proved a force to reckon with. Lawrence was ultimately able to generate enough highly enriched uranium for the Hiroshima bomb; however, his approach was scrapped in favor of a competitor's technology in the early postwar.

Lawrence comes off as particularly shallow and unreflective in the immediate postwar period. He complained that the scientists who participated in the discussions about the domestic control of atomic energy were "frittering away so much time and energy on political problems, when they could be devoting themselves to scientific pursuits." In response to his former colleague J. Robert Oppenheimer's expressions of unease, Lawrence glibly remarked that, "I am a physicist and I have no knowledge to lose in which physics has caused me to know sin." If one believes these sentiments were rooted in true conviction, one might be inclined to give Lawrence the benefit of the doubt. But it is all too easy to read these comments cynically, as Lawrence benefited immensely from taking such unruffled positions about the militarization of science.

Some of Lawrence's political opinions eventually caught up with him. His unwavering support for anti-Communist loyalty oaths and internal investigations, for example, led to an exodus of top-flight theoretical physicists from his laboratory in the early 1950s. He advocated strongly for the thermonuclear "super" bomb in 1949 and later lent his name, and credibility, to many questionable Cold War projects, including the development of a so-called "clean bomb." To many contemporaries, he appeared to be cheapening his reputation as a scientist in order to please his political patrons.

Lawrence's hawkish leanings were in keeping with the sentiments of many physicists involved in defense work at the time, but his politics would eventually go a step further. He played a key role in the "Oppenheimer affair," the hearing conducted by the Atomic Energy Commission that ultimately resulted in the revocation of Oppenheimer's security clearance. When questioned by the chief counsel of the review board before the hearing, Lawrence made disparaging comments about his former friend, stating at one point that Oppenheimer "should never again have anything to do with the forming of policy." Claiming illness and presumably fearing retribution, Lawrence begged out of testifying at the actual hearing at the last minute.

Lawrence's career was not without missteps. His efforts to set up the Livermore laboratory using the Radiation Laboratory as a model (cheap workers surrounding an all-powerful director) produced a string of nuclear fizzles. Funding became harder to procure when the people judging his project proposals were fellow physicists who proved less susceptible to his infectious optimism. A brief foray into private industry in the 1950s ended in a lackluster failure. The things Lawrence was good at (overbudgeted one-off technical accomplishments) were precisely the opposite of the requirement for building and manufacturing profitable consumer electronics.

Still, no one could accuse him of a lack of initiative, ambition, or energy. But the endless work appears to have taken a heavy toll—in 1958, Lawrence died from complications from stress-related ulcerative colitis.

Ultimately, it is difficult to judge Lawrence only by his legacy in physics, without considering the post–Cold War environment in which he worked. The era in which individual governments forked over huge sums of taxpayer funding to build monuments to discovery, with the vague expectation of military benefits, appears to have ended.

In the end, Hiltzik seems uncertain as to what genre the book is to belong: blushingly flattering at times, damningly critical at others, he never quite gets inside Lawrence's head. What was it that drove the man: a true devotion to science or to ego? Is he a scientific hero or a cautionary tale?

REFERENCES AND NOTES

1. P. Galison, B. Hevly, Eds., *Big Science: The Growth of Large-Scale Research* (Stanford Univ. Press, Stanford, CA, 1992).
2. H. Childs, *American Genius: The Life of Ernest O. Lawrence* (Dutton, New York, 1968).

10.1126/science. aac7351

RED POPPY
[*Ignis Ubinanae*]
Flower with fiery plasma.

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BIOTECHNOLOGY

Bio Art: Altered Realities
William Myers
Thames and Hudson, 2015. 256 pp.

In *Bio Art*, writer and curator William Myers offers a timely look at the implications of new and emerging biological technologies as interpreted by more than 60 contemporary artists. Combining microorganisms with traditional media, pieces such as Julia Lohmann's *Co-Existence* (2009) probe our evolving understanding of the relationship between human and nonhuman organisms, while others, including Mara Haseltine's artificial oyster reefs (*Oyster Island*, 2010), explore how we are reinventing our roles in the earth's ecosystems. Still other works—including Eduardo Kac's transgenic petunia, which includes a gene isolated from the artist's own body (*Natural History of the Enigma*, 2008)—encourage us to reflect on the possibilities enabled by synthetic biology. Thoughtful and provocative, *Bio Art* is a compelling contribution to the biotechnology conversation.

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