THE BITTER AFTERTASTE OF TECHNICAL SWEETNESS

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Technical sweetness. Scientists and engineers use this phrase when a puzzle's solution presents itself, when all the pieces fit beautifully and functionally together, when success at the particular endeavor presents itself in a neat package. Technical sweetness is alluring, consuming, and, as we can see in the story of Victor Frankenstein, potentially blinding to what might follow from the solution being sought. Scientists who are driven by technical sweetness can fail to see what might be obvious to those with a bit more distance—that despite some projects' allure, sometimes completing the project is not desirable.

When Victor first discovers the secret to life, he is so overwhelmed by his success that he fails to share it with his colleagues and instead accelerates toward a full-fledged test of his insight—Can he animate a body devoid of life? In his desperation to complete this test, he pushes himself to the breaking point, fully in the thrall of the technical sweetness of his work. He stops communicating with his friends and family and disengages from the social connections that might give him a better perspective on his pursuits. He senses that all is not right—that his reluctance to share his work might mean something more than a desire to guard the secret until confirmation is achieved; only once his creation awakes does he realize that it might not have been a good idea to create such life. Indeed, he recoils from what he has done, running from his creation for two years. In the end, he spends the rest of his life in a dark dance with the creature, attempting to forestall further horrors from being inflicted upon humanity.

Victor is, of course, a fictional character in a gothic horror story, but the arc of his work—from the capture of his imagination by an idea to the theoretical discovery (which he refuses to share), to the sequestration of his work until a complete empirical manifestation of it, to a revulsion in his ultimate success, and finally to an embrace of his responsibility and pursuit of his creation in an attempt to restrain it—is not something that resides solely in the realm of fiction. Such an arc can be found in one of the most momentous scientific projects of the twentieth century: the creation of the first atomic bombs.

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The story of the pursuit of the atom bomb is not a perfect reflection of Victor's story because the former involves the work of many scientists, not just one. It is also the story of an endeavor that was constantly in the shadow of fraught moral decisions and catastrophic world war. But much of the arc of this story mirrors the arc of *Frankenstein*, and the lesson of the need to resist the allure of technical sweetness is made manifest even amid the complexities.

In late 1938, Lise Meitner and Otto Frisch discovered the process of fission in atomic nuclei and spread the word throughout the international physics community. Before this discovery, most physicists thought that using nuclear physics for practical purposes like energy production and weapons was utterly impractical, and indeed some relished this lack of practical application of their work. But with the discovery of fission, all that changed. The nuclear physics community in the United Kingdom and the United States immediately began not only to speculate about but also directly to investigate whether fission opened the door to practical use, whether enough neutrons resulted from the fission of a uranium nucleus to support a chain reaction, and what sorts of materials could be used to increase the likelihood of a chain reaction. By December 1942, Italian physicist Enrico Fermi created the first self-sustained nuclear reaction (with slow neutrons) in a laboratory located in the squash courts beneath Stagg Field at the University of Chicago, and the Manhattan Project to build that bomb (a fast neutron reaction) was well under way. The Manhattan Project comprised research and development at many sites, especially large industrial sites at Oak Ridge, Tennessee, and Hanford, Washington, as well as the building of Los Alamos Laboratory, where scientists were sequestered to research how to design and test the first atomic weapons.

Scientists traveled to the isolated Los Alamos site under secrecy and, once there, were under strict orders not to discuss the project outside of the inner laboratories, called the Technical Area. Scientists were focused on achieving the goal, a workable atomic weapon, and not on whether doing so was a good idea. Given most scientists' impetus—concern that the Nazis might develop such a weapon first—such a focus was understandable.

Situated at the timberline more than seven thousand feet atop a mesa in New Mexico, Los Alamos was a heady atmosphere in which to work: led by the brilliant J. Robert Oppenheimer, filled with past and future Nobel Prize winners, and pressurized by the war. The site grew rapidly from about one hundred people in the spring of 1943 to more than six thousand by the end of the war (Bird and Sherwin 2005, 210). The scientists at Los Alamos confronted a number of technical challenges, particularly regarding how

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to ensure that maximum energy would be released from the hard-to-collect fissile material being produced at Oak Ridge (enriched uranium) and Hanford (plutonium) (Rhodes 1986, 460–464). But by late 1944, the initial impetus behind the program was undermined. Reports coming back from successful Allied pushes into German territory revealed that the Nazis' atomic efforts were nowhere close to producing weapons. In fact, Germany had failed to produce a functioning nuclear reactor, something achieved in the United States two years earlier.

For one scientist, Polish physicist Joseph Rotblat, the realization that the original motivation to produce an atomic weapon had evaporated provided sufficient reason to leave the project. He resigned from Los Alamos in December 1944. However, before his departure, he was forbidden from discussing his decision with the other scientists at Los Alamos (Brown 2012, 55). A moment for moral reflection among the Los Alamos scientists was lost.

By May 1945, even as the European war came to an end, work on the weapon accelerated. Oppenheimer recalled later that the scientists never worked harder than in the summer of 1945 (Szasz 1984, 25). Producing a weapon before the end of the war, that could be used to end the war, became a paramount driver, in part because many of the scientists at Los Alamos had shifted their justification for pursuing the weapon to the ending of *all* wars. Many thought that only if the weapon were used to end the current war would humanity appreciate how truly destructive such weapons could be and thus be motivated to end war permanently.

Efforts at Los Alamos from February 1945 through the summer were focused on a test of the plutonium bomb. Because of the much more complex mechanism needed to produce a weapon with plutonium, scientists were quite unsure whether it would work. Only a trial with real plutonium could produce an adequate test of the mechanism. This test would be the Trinity test, the first atomic explosion on the planet, held on 16 July 1945.

The work leading up to this test was nothing short of feverish. Getting all the technical details, calibrating measuring equipment, and creating contingency plans took massive effort. Three possible outcomes presented themselves: (1) the test weapon could be a dud, no more powerful than a usual ordnance explosion; (2) it could be massively destructive, killing many on site and causing a national emergency; or (3) it could be the weapon they hoped for, impressive but not out of control (Szasz 1984, 79). Much to the relief of the scientists present, the last possibility proved accurate, which meant that their work was a success and that they had produced a usable

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weapon. They had not wasted their effort during the war, and they had survived to tell the tale.

The scientists reacted in different ways to their success. The first thing Oppenheimer said when the bomb went off was an exultant "It worked!" The scientists had mostly expected a much smaller explosion, as revealed by the betting pool for the yield at Trinity (Szasz 1984, 65–66). Oppenheimer picked the equivalent of three hundred tons of TNT; most scientists picked yields much less than ten thousand tons. In fact, the weapon produced a yield closer to twenty thousand tons of TNT. Along with relief and excitement at the technical success, the visual and visceral impact of the explosion impressed many of the witnesses. Oppenheimer later recalled that these words from the Bhagavad Gita went through his mind: "I am become death, the destroyer of worlds" (quoted in Szasz 1984, 89). I. I. Rabi was at first thrilled but then overwhelmed by the implications of what he and his fellow scientists had done (Szasz 1984, 90). As Victor Weisskopf wrote, "Our first feeling was one of elation, then we realized we were tired, and then we were worried" (quoted in Szasz 1984, 91). The technical sweetness of the project was over, and now the scientists had to confront what their success meant in the full complexity of the world. Test director Kenneth Bainbridge quipped, "Now we are all sons-of-bitches" (quoted in Bird and Sherwin 2005, 309).

It took time for some of the scientists to fully grasp the moral weight of what they had done. After the use of the weapons at Hiroshima and Nagasaki, which helped bring a sudden end to the war, many of the enlisted men at Los Alamos celebrated, but the scientists were subdued and sometimes physically sick, overwhelmed by what they had helped achieve (Bird and Sherwin 2005, 317). When Phil Morrison and Bob Serber returned from Japan to Los Alamos at the end of October 1945 with firsthand accounts of the impacts of the bombs (Bird and Sherwin 2005, 321), scientists who had worked on the project now faced the grim reality of their success and, seeing it clearly, committed themselves to making their work as beneficial for humanity as possible.

Different scientists sought to shoulder responsibility for their creation in different ways. Some worked to ensure that atomic power was placed under civilian control, and their efforts led to the US Atomic Energy Commission. Some sought to forestall an arms race with the Soviets by advocating for international control of atomic technology. Some spread the word of how destructive the bombs were, hoping to prevent all future wars. Some pursued even more powerful weapons, their sights set on keeping Soviet

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totalitarianism at bay. And some pursued the peaceful uses of the atom. None escaped a sense of responsibility for their work.

We can see in the arc of the story of scientists at Los Alamos echoes of Victor Frankenstein's story. From the intense pursuit to the dawning realization of the downsides of success and the attempt to ameliorate such success, such parallels were noted at the time. In notes for a meeting of the Interim Committee (a high-level policy committee for nuclear weapons) on 31 May 1945, Secretary of War Henry Stimson wrote that the bomb "May *destroy* or *perfect* International *Civilization*, May [be] *Frankenstein or* means for World Peace" (quoted in Rhodes 1986, 642, emphasis and capitalization in the original). For the scientists engaged in the project, the Frankenstein nature of it remained out of focus until its completion. With technical success and technical sweetness attained, the fraught moral questions that came with success clarified painfully.

Mary Shelley's novel *Frankenstein* is a prescient parable, a gripping nontheistic version of Goethe's *Faust* that spells out the horror that can accompany success as we pursue science and technology. Even as science has grown as an enterprise, even as the collective nature of the scientific endeavor has become clear and big science has taken a more central place in scientific culture, the arc followed by Victor—the solitary scientist—is still relevant. Whether scientists work by themselves or in collaboration, they continue to confront the allure of technical sweetness and its blinding power as they grapple with their responsibilities for their work in the twenty-first century.

Scientists whose work suddenly raises the red flag—for example, those whose work gets labeled "potential dual-use research of concern"—often balk at the imposition of restrictions and the requirement of deeper reflection. The lure of technical sweetness, of continuing to pursue success in their area of expertise, makes it hard for those scientists to see, much less weigh seriously, the downsides of their work. Even with increasing efforts to create structures through which scientists can address the thorny problems that can arise when pursuing new scientific and technical capacities, technical sweetness can still blind them to the need to reflect on the implications of their work and the imperative to act, before completion, to ameliorate the impact of success.

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APPENDIXES

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