The first decades of the twentieth century were marked by two revolutionary scientific accomplishments, the theory of relativity and quantum mechanics, with repercussions still felt today. Relativity theory and quantum mechanics became the two most important branches of “Modern Physics” that emerged as an alternative to “Classical Physics” (a term often used interchangeably with that of “Newtonian” or “Galilean” physics). No field of science (from astronomy to the life sciences), no field of knowledge (from philosophy to sociology), and no artistic practice (from architecture to the fine arts) was left untouched by these investigations into the nature of our physical universe.

For many observers far and near, modern physics became a catalyst for much that was new about the modern world. For the most part, cultural ramifications were celebrated and promoted, sometimes considered as emerging from a kind of “genetic connection,” while at other times they were seen as unwarranted extensions of science into unrelated territories. Particularly controversial was the relation of relativity theory to other forms of relativism (cultural, moral, and popular). When Einstein was asked to comment about the similarities between his work and the “new artistic ‘language’” associated with Picasso, cubism, and modern art, he answered decisively: It had “nothing in common” with it.

How did the new physics affect European intellectual thought? Not only did new insights into the nature of the physical universe affect how intellectuals across fields thought about basic concepts (such as time, space, and the nature of matter and light), but they also had to contend with the growing status of physics as a field of knowledge in the public sphere. The question of how non-scientists (philosophers, intellectuals, or humanists) should react and adapt to these changes became a concern for decades to come. Increasingly after World War I, a tightknit community of expert elite physicists played prominent roles in public spheres, far surpassing the influence that nineteenth-century scientists, such as Louis Pasteur, Charles Darwin, and Alexander von Humboldt, had once had on the culture of their time. The new role of physicists as spokespersons for the universe disrupted traditional hierarchies between physics and philosophy, as well as that between the sciences and the humanities and arts.

The main scientific insights of these scientific revolutions remain, for the most part, valid today. Both fields opened up fertile research programs leading generations of scientists to many future discoveries. Modern physics paved the way for the development of entire new fields of research, from nanoscience to, most recently, gravitational waves. A host of new technologies central to the modern world were widely understood as “spin-off” effects emerging from theoretical research, further securing the status of theoretical physics in public and academic circles. The world of radio, of electrical, telephone, and telegraph communications, of nuclear energy, satellites, space exploration, and global positioning systems (GPS) became associated with the lessons of the theory of relativity (and mostly with Einstein), while the world of microelectronics (transistors and semiconductors), lasers, atomic clocks, electron microscopy, magnetic resonance imaging (MRI), and light-emitting diodes (LEDs) was associated with quantum mechanics. New laws sought to explain the universe at two extremes, microscopic and macroscopic, as the world became more extreme in other ways too.

The relation of theoretical science to pure knowledge and of technology to applied knowledge became a topic of wide concern. In addition, a growing number of thinkers attributed to technology an outsized role in modernity, some celebrating its benefits while others stressed its perils (the latter often citing military innovations). Widespread fears of the potential of science and technology running amok led to new discussions about the role of human agency within larger technological systems and networks.
The Modern in Modern Physics

What exactly is modern about modern physics? A common way of understanding the main scientific purport of these fields has been in terms of their radical redefinition of traditional concepts of time and space. As is well known, the theory of relativity took time to be a fourth dimension next to the three dimensions of space. Although this insight can be found in different forms before the twentieth century (and can even be traced to ancient philosophy), Einstein’s theory of relativity introduced it alongside the more radical claim that no privileged “frame of reference” existed, that is, that for every point in space-time the laws of physics are the same, or invariant. These two insights were related to the discovery of time and length dilation: Measurements of time and length were proven to vary in relation to the velocity of translation of a system in motion relative to another one. In 1908 the mathematician Hermann Minkowski explained the importance of the theory of relativity in these terms: “Henceforth, space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.”

Quantum mechanics changed our common perception of space and time in yet other ways. First, the “uncertainty relation” (associated with the work of Werner Heisenberg) posed an absolute limit on the knowledge that could be obtained (non-commuting observables such as position and momentum could not be determined beyond a certain limit, $\Delta x \Delta p \geq \hbar / 2$). Second, the possibility of “non-locality” and “entanglement,” showing how one particle could affect simultaneously another one separated at arbitrarily large distances, violated the theory of relativity. Third, quantum mechanics introduced essentially discrete changes in the state of nature, called “quantum jumps,” to explain certain characteristics of atoms. In addition to these revolutionary claims, scientists noted that light seemed to behave as both wave and particle, leading some scientists to advocate for a more general “theory of complementarity” where every object in the universe was considered as having both particulate and wavelike qualities. Finally, by showing how performing a measurement could change the phenomenon under investigation (as in the “double-slit experiment”), quantum mechanics introduced new questions about the relation of the universe to consciousness. To explain the philosophical and physical meaning of these effects, the Danish physicist Niels Bohr developed an explanatory

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framework known as the “Copenhagen interpretation,” stressing indeterminism in the laws of the universe.

Modern physics emerged from the research of many investigators across Europe. Einstein emerged as an outsized public figure, towering above other scientists in terms of public recognition. Max Planck, Erwin Schrödinger, Werner Heisenberg, Max Born, Pascual Jordan, Wolfgang Pauli, John von Neumann, and Paul Dirac, among others, were other key contributors to quantum mechanics.

The history of modern physics is one of the most scrutinized yet also most distorted topics in the history of science. What follows is an attempt to bring precision to some of the most controversial aspects of these revolutions in relation to intellectual thought. These topics – ideal cases for understanding the relation between theory and experiment and the relation of science to other areas of knowledge – show how the public was mobilized by a community of experts. Scientists divided their time between private research and public dissemination, promoting science as associated with moral values (objectivity, civil discourse, democracy, and anti-totalitarianism).

The Turn of the Century (1898–1902)

Before there can be a solution to a problem, there must be a problem. Two scientists and close collaborators, Henri Poincaré in France and Hendrik Lorentz in the Netherlands, were most responsible for articulating the challenges faced by science at the turn of the century. Both ended up by having complicated relationships to Einstein’s proposed solution to the “crisis” of science they described, and both in many ways anticipated – but did not follow through – the research programs associated with Einstein’s work.4

At the turn of the century a number of prominent scientists and intellectuals perceived that science was “bankrupt” and in “crisis.” The legacy of anti-clerical writers of the previous century, such as Hippolyte Taine and Ernest Renan, faced a backlash as intellectuals noted that these authors had placed too much hope in science. In France, “the crisis of science” movement encapsulated one aspect of widely noted societal ills connected to a generalized crisis of authority and widespread discontent with various aspects of life at the fin de siècle.

Signs that a crisis in science was brewing came to a tipping point when Poincaré, a highly respected mathematician and scientist (cousin of Raymond Poincaré, President of France during the years 1913–1920), noted how, in the realm of electricity and magnetism, the laws of physics seemed radically different. In work published in 1898 Poincaré explained how these laws showed a completely new aspect of time where it was no longer a single or unified concept and where no master clock connected to the universe could ever be found. In the *Revue de Métaphysique et de Morale* he stated that, “Of two watches, we have no right to say that the one goes true, the other wrong; we can only say that it is advantageous to conform to the indications of the first.”\(^5\) In light of this research, Poincaré argued that another of the most cherished principles associated with Newton, the principle of reaction, should no longer be considered universally valid. Poincaré concluded by leaving physicists with two options: either abandon cherished principles based on the old concepts of time and space, action and reaction (basically, all of Newtonian mechanics) or change the current understanding of physics: “Ainsi se trouveraient condamnées en bloc toutes les théories qui respectent ce principe, à moins que nous ne consentions à modifier profondément toutes nos idées sur l’électrodynamique.”\(^6\)

By the end of the nineteenth century, Poincaré had already seen many of the revolutionary consequences of the “new dynamics.” But instead of pushing for radical changes in the discipline of physics, he opted for a conservative approach that safeguarded long-held beliefs by applying minor corrections to particular scientific theories.

Poincaré studied the work of Lorentz closely. “The Dutch Poincaré” had made a reputation for himself by focusing on electricity rather than on traditional mechanics.\(^7\) Lorentz revealed how different the laws of the former were, and investigated instances when the two could be reconciled and when they could not. He published prolifically on these topics, establishing a new relation between energy and mass that depended on acceleration.\(^8\) Thereafter the

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relation between the concepts of mass and energy, in addition to new space-time relations, became an active area of research that would characterize modern physics, culminating with Einstein’s General Theory of Relativity.

The St. Louis World’s Fair

Poincaré’s widely anticipated conference at the Congress for Arts and Sciences at the St. Louis World’s Fair (September 24, 1904) laid out “The Present State and Future of Mathematical Physics.” 9 His presentation portrayed physics at the cusp of a “transformation profonde.” 10 On account of its non-technical language, the lecture was quickly reprinted in the Revue des Idées. 11 Poincaré noted that “nous sommes assurés que la malade n’en mourra pas et même nous pouvons espérer que cette crise sera salutaire,” recounting how – despite the revolutionary implications of the new physics – it remained identical to the old physics at a first-order approximation. 12

Poincaré followed this presentation with the publication the following year of “Sur la dynamique de l’électron,” which he presented on June 5, 1905 to the Académie des Sciences. 13 Therein he explained how the “Lorentz transformations” (the new formulae of time and space describing electrodynamic phenomena central to Einstein’s theory) could be expressed in terms of the quadratic expression \( x^2 + y^2 + z^2 - t^2 \) with “invariant” properties in a “space of four dimensions.” 14 In both papers, Poincaré discussed the possible existence of gravitational waves and expressed how further astronomical tests would be possible. Poincaré considered these insights as an important “modification” of the laws of Newton (in the shorter Comptes Rendus version) and as “analogous” to the Copernican revolution (in the longer text). He warned readers that, if one changed how physicists traditionally conceived of time to match the new insights, a cataclysm would follow, comparable to that which “befell the system of Ptolemy due to the intervention of Copernicus.” 15 His research reached an

even wider public with the appearance of the widely read *The Value of Science* (1905) describing the “new mechanics.”

Einstein followed the work of both men closely. His areas of interest focused on the same topics, mainly the nature of light and electricity, Brownian motion, the relativity principle, and the relation between mass and energy and acceleration and gravitation. In the *annus mirabilis* of 1905, Einstein published four ground-breaking papers that positioned him as one of the most promising young physicists of his generation. For the next decade he would continue to labor on these topics, respond to criticisms, and eventually integrate most of these insights into a single theory known as the General Theory of Relativity – the fulfillment of his “boldest dreams.”

In 1916 Einstein developed a set of “field equations,” simultaneously with the mathematician David Hilbert, showing how these new concepts of time and space, matter and energy, inertia and gravitation matched against actual astronomical measurements of our solar system. The new theory was a great scientific achievement, but for many physicists the price to pay seemed too high, since not only did it require changing the definitions of the most basic concepts in physics, but it was also based on a complex non-Euclidean mathematical structure which then had virtually no applicability beyond explaining previously known results.

### The Eclipse Expedition

Attention to General Relativity came not from physics but from astronomy. A group of astronomers led by Frank Watson Dyson, the Astronomer Royal of the Greenwich Observatory, and his chief assistant Arthur Eddington organized an eclipse expedition to test one of the central claims of the General Theory: the bending of light by the gravitational pull of the sun. Einstein argued that light should be considered as an ideal measurement standard for both time (frequency) and space (wavelength), so gravitational effects on light could be used as evidence for the warping of the very fabric of time and space itself.

The expedition results “confirmed” Einstein’s theory and were announced with great fanfare at the Royal Astronomical Society in Burlington House in London. Although Einstein’s theory was neither the first nor the only one to

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propose that gravity would affect light, the published article on the expedition results laid out in its first paragraphs only three possible explanations for the behavior of the light measured during the eclipse. The first option proposed that there was no gravitational effect, the second one concerned an effect equivalent to that of gravity on “ordinary matter” (as in the traditional Newtonian law of gravitation and theory of matter), and the third one would explain a result twice that amount “in accordance with Einstein’s generalized relativity theory.” The measurements of the photographic plates from the expedition matched with confidence the value for deflection given in the third case.

The public presentation of the eclipse results was covered widely by the popular press, inaugurating a means of dissemination of science via press release that would later become common practice for large-scale projects. In 1919 Einstein’s name appeared on the cover of newspapers around the world announcing a revolution not only for physics, but for our general understanding of time and space. The headline of The Times read “Revolution in Science/ New Theory of the Universe/ Newtonian Ideas Overthrown,” and the New York Times announced “The Lights of the Heavens Askew.” Shortly after the widespread news coverage, Einstein explained that in Berlin “every child knows me from photographs” and described himself as a media King Midas, who turned everything he touched into news: “Like the man in the fairy tale, whose touch turned everything into gold, thus it is with me, with everything turning into banner line news.”

Most accounts of the importance of Einstein’s work after the eclipse expedition were based on a standard model where the value of science was understood in terms of hypothesis creation, theoretical prediction, and experimental confirmation. The model for this kind of scientific production became popular after the French astronomer Urbain Le Verrier’s discovery of Neptune was widely publicized in 1846. At that time, Le Verrier’s discovery became a symbol for how mathematics and theoretical physics could be used

18 The third option was twice the amount of the first one because in Einstein’s theory the displacement “becomes magnified as the speed increases, until for the limiting velocity of light it doubles the curvature of the path.” Dyson, Eddington, and Davidson, “A Determination of the Deflection of Light by the Sun’s Gravitational Field,” 291–292.
19 The first should show no displacement on the measured photographs, the second 6”.87, and the third option 1”.75.
20 The Times (November 7, 1919 ); and New York Times (November 10, 1919).
to predict new phenomena. The astronomer was widely applauded for
discovering a planet not with a telescope, but “avec la pointe de sa plume.”

Le Verrier’s success in leading observers to find a new planet (which was
eventually named Neptune) fueled a race to explain another anomaly in
Newtonian celestial mechanics: the perihelion of Mercury. Observations of
its actual movement differed greatly from the value obtained through math-
ematical calculations.

The problem of the perihelion of Mercury captivated some of the most
ambitious scientists of the nineteenth and twentieth centuries. In Science and
Method (1908), Poincaré asked whether the motion of the perihelion of Mercury
was “an argument in favor of the new Dynamics” or “an argument against it”
concluding that it was “the only appreciable effect upon astronomical observations”
of the new theories. The most recent calculations using the new theories
showed that the perihelion occurred “in the same direction as that which has
been observed without being explained, but [was] considerably smaller” than the one
obtained with a traditional (Newtonian) definition of mass. In the years that
followed, Einstein decided to explore other ways to explain the observed value
of the perihelion by proposing changes in mass due to velocity. In 1915 he
proposed a theory that “has as a consequence a curvature of light rays due to
gravitational fields twice as strong” as previously thought. With these adjust-
ments, he matched the value of the most trustworthy observations (Einstein’s
calculations resulted in 43″ per century while observations amounted to 45″ ±
5″). The new calculated number (nearly double the Newtonian one) would
also produce a doubling in the amount of light deflection by gravitational
forces that would be tested during the eclipse expedition.

Einstein’s magisterial publication “The Foundation of the General Theory
of Relativity” appeared the following spring in March 1916. It conformed to
the model of scientific discovery that had buttressed the prestige of science in
the nineteenth century after Le Verrier’s discovery. The text mentioned the
effects of the bending of light by gravity, the perihelion of Mercury, and the
red-shift of the spectrum of light as possible tests for this theory. These effects

22 Observations of the planet Uranus had shown that its orbit did not move exactly as
predicted by the laws of Newton. Le Verrier hypothesized that the gravitational pull of
another planet could be used to explain this discrepancy and accurately calculated
where the planet could be found. François Arago, Astronomie populaire, ed. L. Guérin,
24 Albert Einstein, “Erklärung der Perihelbewegung des Merkur aus der allgemeinen
Relativitätstheorie,” Sitzungsberichte der Königlich Preußische Akademie der Wissenschaften
(1915), 831–839.
came to be known as the “three classic tests” of relativity. While the value of the perihelion of Mercury had been known for decades, at the time of publication experimental work on the other two related phenomena was still incipient and inconclusive.

While the three classic tests were used to prove General Relativity, after 1907 Einstein increasingly invoked the Michelson–Morley experiment as evidence in favor of the Special Theory of Relativity. Historians and philosophers of science, however, have noted that in both cases the actual reliance of Einstein’s work on experiment is more complicated than how it was presented in his scientific papers and by the press.25

Einstein Simplified

Newspapers of the time reported local news alongside science with cosmological and universal implications to recruit even larger audiences.26 During the Victorian era science popularization had occurred mainly through large public lectures and specialized journals, such as Norman Lockyer’s Nature and Camille Flammarion’s Cosmos, but in the twentieth century newspapers and the daily press increasingly took on the role of publicizing science to an expanding public.

The New York Times coverage of Eddington’s packed Trinity College lecture to students was announced with the headline “Professor Eddington, 6 Feet to the Eye, Explains How It May Be Really Only 3 Feet.”27 The astronomer asked readers to imagine an aviator traveling at 161,000 miles per second, about nine-tenths the speed of light. The aviator’s watch would seem, to a stationary observer, to tick twice as slowly. He invited students to “suppose that you are in love with a lady on Neptune and that she returns the sentiment” to illustrate the complexities behind the scientific understanding of the “now” concept.28 The mathematician Bertrand Russell continued these popularization efforts, warning readers that circular dinner plates in the dining car on a speedy train would look oval to stationary outsiders. He used the example of flies landing on stagnant pools as models

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for stars bending space-time, and recounted other similarly astounding examples, such as cigars and dental appointments lasting twice as long: “What a situation for envy! Each man thinks that the other’s cigar lasts twice as long as his own. It may, however, be some consolation to reflect that the other man’s visit to the dentist also lasts twice as long.”

The most successful of these evocative stories became known as the twin paradox. It was originally due to the physicist Paul Langevin, who did not mention twins, but referred to a voyager on the rocket ship of Jules Verne. Einstein considered it “the thing at its funniest.” Later even more colorful examples featured twins, with one of them leaving Earth to travel at close to the speed of light and eventually returning to see that he had aged less rapidly than the sibling who remained at home.

Popularization accounts often stressed that the layman’s understanding of such complex theories was necessarily limited. The New York Times special cable from Berlin reported Einstein as claiming that, despite the revolutionary importance of his theory, “no more than twelve persons in all the world could understand it.” This message was reinforced through other means, including film. An American short film produced by Fleischer Studios of Superman and Betty Boop cartoons spread the message “that only twelve men in the world could understand” Einstein’s theory.

The narrative of prediction of observables from abstract mathematics drew from another trope prevalent in accounts of science from the time of Newton, where genius men were portrayed as working in isolation and at a distance from mundane concerns. Einstein was described in the daily press as working “close to the stars he studies, not with a telescope, but rather with the mental eye, and so far only as they come within the range of his mathematical formulae.” A title card from the film The Einstein Theory of Relativity read “there sits in a quiet little study in Europe a genius.” These depictions glossed over Einstein’s close attention to experimental work and astronomical measurements, his experience as a patent clerk, and his work as a consultant for the military and industry.

34 Fleischer, The Einstein Theory of Relativity.
Conventionalism and Differences with Poincaré

The portrayal of Einstein and theoretical physics in public forums stood in sharp contrast with the view of science held and promoted by some of Einstein’s most prominent interlocutors. In France, Poincaré’s philosophical stance with regard to science was known as “conventionalism” or “commo-disme.” The value of scientific theories resided in how they helped scientists describe physical phenomena in a useful and pragmatic manner. Conventionalism stressed the tight relation between theory and experiment, highlighted the reliance of theoretical science on practical mathematics, underlined the role of technological context, and stressed the benefits of practical considerations in the production of knowledge. It was a far cry from more sensationalist accounts of science where unexpected discoveries arose from theoretical predictions emerging from the mind of isolated scientists, and which did not capture dramatic headlines.

Conventionalism was amply criticized by its detractors for proposing a view of science as somewhat provisory, tentative, and opportunistic. Yet Poincaré considered scientific theories not as conventions that could be created or changed willy-nilly, but as being so strong that they reflected the true nature of the phenomenon under investigation. However, because Poincaré placed an emphasis on the practice and ease of use of theories and mathematical tools, his accounts contrasted starkly with naïve realist or platonic explanations, on one extreme. On the other hand, he differed from thinkers who believed that science’s grasp of absolute truth was even weaker. Poincaré thus differed from some Catholic scientists and philosophers, such as Pierre Duhem, who described scientific theories as matching very imperfectly against nature (the “underdetermination” thesis), and the philosopher Édouard Le Roy, a student of Henri Bergson, whom Poincaré considered a nominalist for proposing a view of science that considered its power as essentially descriptive.36

Poincaré’s philosophical understanding of the nature of scientific labor affected his estimation of Einstein’s scientific work. In a letter of recommendation written to support Einstein’s application for a professorship in theoretical physics at Zurich, Poincaré described the work of the theoretical physicist as a kind of guided guesswork. This labor could sometimes result in the prediction of new effects that could be corroborated by experimentalists. Einstein’s future success, wrote Poincaré, stemmed from his perseverance and originality.

rather than from anything else: “Since he seeks in all directions one must, on the contrary, expect most of the trails which he pursues to be blind alleys. But one must hope at the same time that one of the directions he has indicated may be the right one, and that is enough.”

Poincaré’s conventionalist approach to science also informed his understanding of relativity theory. In 1902 he wrote to the Nobel Prize committee arguing that Lorentz should receive the prize for discovering some of the central aspects associated with relativity theory. These included the discovery of time dilation, a correct explanation of the Michelson–Morley experiment, and invariance. Poincaré’s letter was signed by some of the most renowned physicists of the time, including Wilhelm Röntgen, Henri Becquerel, and Planck, clearly showing that most of these physicists also attributed some of the central ideas of relativity theory to Lorentz.

Poincaré’s report on Lorentz’s work in 1910 stressed that, in the case of traveling clocks, Lorentz had shown why it was “impossible to detect anything other than relative velocities of bodies with regard to one another, and we should also renounce the knowledge of their relative velocities with regard to the ether as much as their absolute velocities.” On May 4, 1912, two months before his death, Poincaré delivered a lecture in London that would be his last significant statement on the theory of relativity, and that did not even mention Einstein.

**Differences with Lorentz**

While Poincaré gave a central importance to utility and convention in science, Lorentz’s understanding attributed a strong role to epistemology, especially in determining the merits of competing scientific theories. For him, our understanding of time and space as connected to everyday experiences should be accorded strong epistemological value. This benefit should

39 “This principle must be regarded as rigorous and not only as approximate.” Henri Poincaré, “Rapport sur les travaux de H. A. Lorentz, ca. 31 January 1910,” in La Correspondance entre Henri Poincaré et les physiciens, chimistes et ingénieurs, ed. Scott Walter, Étienne Bolmont, and André Coret (Basel: Birkhäuser, 2007), 438.
be taken into consideration when debating about the merits of scientific theories. Einstein disagreed. He at first attached Lorentz’s name to the theory of relativity, referring to it as “the theory of Lorentz and Einstein,” but started to separate himself from Lorentz’s position in 1907, referring separately to “the H. A. Lorentz theory and the principle of relativity.”

Einstein claimed that his particular contribution resided in considering Lorentz’s “local time” to be time in general. Lorentz, in contrast, would continue to refer to the change in magnitude of time measurements as local time, contrasting it with time in general. In the case of length, he referred to the change in magnitude as apparent length in contrast to length in general. Einstein eventually became convinced that there was nothing “local” or “apparent” about these time measurements and that one was as general as the other.

Lorentz, conceding that Einstein could “take credit” for relativity, explained how “Einstein simply postulates what we have deduced, with some difficulty and not altogether satisfactorily.” Lorentz accepted that Einstein was right but claimed that he was right too: “Which of the two ways of thinking you would like to join, is a decision that depends entirely on each individual.” The issues at stake, Lorentz insisted, were epistemological: “The evaluation of these concepts belongs largely to epistemology, and the verdict can also be left to this field.” Scientists were free to chose between them depending on “the mindset to which one is accustomed, and whether you feel most attracted to one or the other view.”

Lorentz’s popular book The Einstein Theory of Relativity called the theory “a monument of science” and extolled the “indefatigable exertions and...
perseverance” of its author. Nonetheless, Lorentz cautioned that “in my opinion it is not impossible that in the future this road [research on the ether], indeed abandoned at present, will once more be followed with good results.” He continued to search for a stable background that could serve as an anchor for an absolute concept of time, be it the ether, a concept of space that could serve as reference point, or some fixed stars in the universe. He still insisted that “one may, in all modesty, call true time the time measured by clocks which are fixed in this medium [space], and consider simultaneity as a primary concept.” Special and general relativity were undoubtedly correct, but they were not the only way to see things: “They will just not impose themselves on us so much as the only possible ones.” The differences between a “physicist of the old school” and the “relativist” resided in the fact that, while both agreed that nobody could “make out which of the two times is the right one,” the old-school physicist was ready to acknowledge that he “preferred” one of them, whereas, for the relativist, “there cannot be the least question of one time being better than the other.” Lorentz’s personal preference was to maintain “notions of space and time that have always been familiar to us, and which I, for my part, consider as perfectly clear and, moreover, as distinct from one another.” While he had introduced the concept of local time, he “never thought that this had anything to do with the real time. The real time for me was still represented by the old classical notion of an absolute time, which is independent of any reference to special frames of co-ordinates. There existed for me only this one true time.” Lorentz continued to believe in his hypothesis: “Asked if

48 The existence of the ether was questioned years before Einstein. Some of the most severe attacks on it came from Poincaré, who is ironically remembered as one of its defenders. “Whether the ether exists or not matters little.” Poincaré, Science and Hypothesis, 211. For the argument that Einstein’s contribution resided in dropping the ether, see John J. Stachel, “1905 and All That, How Einstein Claimed His Place in the Changing Landscape of Physics during His Annus Mirabilis,” Nature, 433(7023) (2005), 215–217, p. 217.
I consider [my hypothesis] a real one, I should answer ‘yes.’ It is as real as anything we observe.”

The presenter of Einstein’s Nobel Prize (given in 1922 for the previous year) explained why the prize was not awarded for relativity, restating (almost verbatim) the view that the validity of Einstein’s theory of relativity “pertains to epistemology and has therefore been the subject of lively debate in philosophical circles,” citing additionally the recent criticism leveled by Bergson during Einstein’s visit to Paris.54

Ernst Mach, The Vienna Circle, and Logical Positivism

During the 1910s and 1920s, Einstein worked hard to combat philosophical or scientific accounts that considered the validity of competing theories in terms of epistemological, practical, or aesthetic considerations. In an article published for general audiences in *Die Kultur der Gegenwart* (1915), he argued against the view that considered a decision on the merits of his theory versus competing interpretations as a matter of choice.55

Einstein’s opinion about Lorentz’s contributions reveals the influence of Ernst Mach’s philosophy on his work. Mach had earlier argued that the most parsimonious theories described the world most accurately, and Einstein explained the benefit of his work over Lorentz’s in these terms. Because there were no “physical grounds (accessible in principle to observation)” for selecting a privileged frame of reference, that concept should not be used. “A worldview that can do without such arbitrariness is preferable, in my opinion,” he concluded, citing Mach.56

Einstein’s strongest critique against the conventionalism of Poincaré appeared nearly a decade after the mathematician had died. “Geometry and Experience” successfully argued that the mathematics used in the theory of relativity should not be considered just a set of convenient tools for describing the universe, but rather as a reflection of the structure of the universe itself. Einstein employed non-Euclidian (more precisely,

Riemannian) mathematics that broke with long-cherished principles (that parallel lines can never cross, that the shortest path between two points is a straight line, and so on) not because these calculating techniques were useful, but rather because the universe itself should be considered as non-Euclidean.

Mach’s philosophical understanding of science was expanded by members of the Vienna Circle, initially known as the Verein Ernst Mach. The group consisted of committed philosophers and scientists who met regularly at the University of Vienna from the mid 1920s to the mid 1930s. For the most part, they promoted a “logical empiricist” view of science that, with few exceptions, considered Einstein’s relativity as a paragon for intellectual achievement. The circle served as a launching pad for logical positivism in the United States after many of its members were forced into exile with the rise of Nazism. Despite the diverse views of many of its members, one unifying goal across various strands of the movement consisted in trying to ground modern scientific knowledge as a structure built up from sense impressions using analytical mathematics. In influential works, and as founders of the journal Erkenntnis, its members defended the value of Einstein’s work, the exceptionalism of science, and why science rightfully stood apart from common sense or non-expert knowledge practices.

Einstein’s own view about science and its relation to philosophy and metaphysics changed significantly throughout his life. During the years when his theory was amply contested and before he received the accolades that would follow, he insisted on a Machian, anti-metaphysical, and objective view of science. But in later years he denounced Mach’s approach as sterile, defended the value of metaphysics, and explained that the differences between physics and metaphysics were of degree and not of kind.

Hans Reichenbach, who had studied with Einstein in Berlin, became one of his most prominent defenders after World War I. Together with other members of the Vienna Circle, Reichenbach developed an epistemological framework for science that would dominate analytical Anglo-American philosophy well into the 1960s. Experience and Prediction, one of the most influential books in the field of philosophy of science (first published in 1938), was notable for its articulation of the logical structure of science and for its account of scientific rationality. Reichenbach separated science into two main parts in order to highlight those process which could be explained logically and separate them from those that could not, arguing that philosophical studies of science should be concerned solely with the former: “I shall introduce the term context of discovery and context of justification to mark
this distinction . . . epistemology is only occupied in constructing the context
of justification." The logical structure of scientific thinking appeared to him
"a better way of thinking than actual thinking." The price to pay for this
logical structure was to completely divorce it from actual scientific practices:
"What epistemology intends is to construct thinking processes in a way in
which they ought to occur . . . replacing the real intermediary links.
Epistemology thus considers a logical substitute rather than real
processes."
By portraying science as necessarily logical and rational,
Reichenbach downplayed those aspects of it that could be seen as merely
conventional or dependent on epistemological assumptions.

With Rudolf Carnap, also of the Vienna Circle, logical positivism expanded
its criticism to the German philosophers Fichte, Schelling, Hegel, and
Heidegger and in France, Bergson. Carnap found no use for "alleged
knowledge . . . which transcends the realm of empirically founded, inductive
science." For many members of the Vienna Circle, metaphysics appeared as
a defect to be eliminated from empirically based rational thought instead of
being a label for aspects of science that could not be tested empirically but
that necessarily accompanied it. Carnap’s Der logische Aufbau der Welt (1928)
attempted to show how a complete scientific system could be built by
combining clear observations with logical mathematics.

Karl Popper’s The Logic of Scientific Discovery (1934) appeared a few years
after Carnap’s Der logische Aufbau der Welt. Like Carnap, Popper was con-
cerned with the problem of “demarcation,” establishing clear criteria for
distinguishing between scientific knowledge and unscientific or pseudo-
scientific beliefs. He proposed a new model for scientific practices based on
a process of hypothesis creation whose strength resided not in how the
hypotheses would be verified by experiments but in their potential for
falsification. The theory of relativity was a central example for Popper,
serving as an aspirational standard for proper scientific work for years to
come.

The aims, methods, and professionalization standards of Analytic (mainly
Anglo-American after World War II) versus Continental philosophy started

57 Hans Reichenbach, Experience and Prediction: An Analysis of the Foundations and Structure
58 Remarks by Carnap written in 1957 appended to Rudolf Carnap, “Überwindung der
Metaphysik durch logische Analyse der Sprache,” Erkenntnis, 2 (1932), 219–241, translated
1959), 80.
59 Peter Galison, “Aufbau/Bauhaus: Logical Positivism and Architectural Modernism,”
Critical Inquiry, 16(4) (1990), 709–752.
differing radically during these years. For the most part, the Analytical school saw philosophy as a discipline that could function as a jury by providing standards of reasonability (a task that can be traced back to Kant’s epistemology, and was rejected later by some postmodern philosophers). It often set science apart from technology, stressed its empirical and rational foundations, and was completely unconcerned with actual scientific practices or historical reality. It was largely this legacy that the anti-logical positivists of the 1970s and the “laboratory studies,” “turn to practice,” and “science in action” movements of the 1980s and 1990s aimed to correct.

Anti-Semitism and Modern Physics

Einstein’s and his allies’ response to criticisms needs to be placed in the context of direct anti-Semitic attacks, such as those that took place in Berlin (August 1920) and in Bad Nauheim (September 1920). During these years, Einstein considered assessments of his theory as completely politicized: “Belief in this matter [whether relativity theory is correct] depends on political party affiliation,” he wrote to a friend.60 The relation of modern physics and anti-Semitism became even more charged as Einstein and other physicists took on increasingly public positions on the pressing political questions of their time, such as the League of Nations and Zionism. In certain cases, the links between certain scientific views, philosophical stances, and political affiliations were clear and sometimes extreme.61

The relation between Einstein, anti-Semitism, and politics informed how many thinkers conceived of a general relation between science and politics more generally for the rest of the century.62 Some of the first sociological studies of science, such as Robert K. Merton’s “Science and the Social Order” (1938), described an inevitable “conflict between the totalitarian state and the scientist” by reference to attacks against Einstein’s theory of relativity by Johannes Stark and Philipp Lenard.63

61 The Russian revolutionary Vladimir Lenin attacked Ernst Mach in his defense of Marxist materialism; the physicist Philipp Lenard was nearly killed by students protesting against his views about the murder of Walther Rathenau; Friedrich Adler, a candidate at the ETH for the physics professorship later held by Einstein, shot and killed the Austrian president; Moritz Schlick of the Vienna Circle was murdered by a student with radical national socialist views.
Anti-Semites, such as Stark and Lenard, frequently co-opted non-anti-Semitic critiques, making it difficult to separate politically or racially motivated attacks from other kinds of critiques. Those scientists and philosophers who questioned the merits of Einstein’s work, but did not want to be associated with anti-Semitism, often stressed their support for Einstein as an individual. Lorentz, for example, actively supported Einstein personally and professionally, despite their differences. Similarly, Bergson expressed his admiration for Einstein as a person and physicist, limiting his critique to certain key points around his theory.  

In Germany, Stark and Lenard, two of the most vocal opponents of Einstein, expanded their target to theoretical physics in general. They protested against a particular way of doing and presenting science that they considered dangerous, foreign, and associated with the Jewish race. In *Nature*, Stark complained that “a flood of propaganda for them is started by articles in journals and newspapers, by text-books and by lecture tours, if possible around the world.” Arguing that “whether the culprit is a Jew or not” was irrelevant, but lamenting that they were securing power by acquiring “numerous chairs in physics, and above all in theoretical physics,” his targets were nonetheless clear.

National Socialist and anti-Semitic critiques were part of a larger *Deutsche Physik* movement, a nationalistic initiative that argued for science by and for the state limited to practical and social usefulness. In their role as public servants, professors of physics and heads of national institutes and laboratories represented the state and were often judged in terms of their contribution to it.

The idea that science was and should be international emerged only during this period and in direct response to these historical events. Einstein’s “Internationalism and Science” (circa 1922) cited with approval the words delivered by the chemist Emil Fischer at the Royal Prussian Academy of Sciences: “Whether you like it or not, gentlemen, science is and always will


66 Anti-Semitism flared up in earlier debates about Einstein’s priority, as his enemies volunteered lesser-known researchers as deserving of credit. In some cases, alternative theories of credit attribution and accounts of what amounts to a “discovery” in science in general were proposed, but, for the most part, these alternative proposals were quickly delegitimized. Milena Wazeck, *Einsteins Gegner: Die öffentliche Kontroverse um die Relativitätstheorie in den 1920er Jahren* (Frankfurt: Campus Verlag, 2009); and Milena Wazeck, “Marginalization Processes in Science: The Controversy about the Theory of Relativity in the 1920s,” *Social Studies of Science*, 43(2) (2013), 163–190.
be international.” 67 This characterization of science replaced the older view that considered it as defined by “national” styles of thinking, such as Duhem’s characterization of British science as emerging from the “ample and shallow” minds of the British compared with the “narrow and deep” ones of his compatriots. 68

Bergson and Continental Philosophy

A key moment in the relation of physics to European thought revolved around Einstein’s assertion, during a meeting at the Société française de philosophie (April 6, 1922) with Bergson present, that “il n’y a donc pas un temps des philosophes.” 69 Bergson objected to the shutting out of philosophy from discussions about the nature of time during the meeting and in Durée et simultanéité. When Einstein was finally awarded the Nobel Prize the presenter noted that “it will be no secret that the famous philosopher Bergson in Paris has challenged this theory.” 70

The debate between Bergson and Einstein became a reference point in discussions about how philosophers and other intellectuals should engage with science for the rest of the century. Bergson argued that a hidden philosophy underlay Einstein’s science, concluding that “Einstein is the continuator of Descartes.” 71 Although Bergson was frequently considered to have misunderstood the facts of science, he considered his critique philosophical: “The theory was studied with the aim of responding to a question posed by a philosopher, and not by a physicist.” 72 Bergson argued that some of Einstein’s most outlandish claims (such as time dilation and the twin paradox) seemed to rest on unacknowledged assumptions (such as differences in travel trajectories). For him, the “really real” aspects of the theory hardly called for such a revolutionary interpretation. Bergson considered

70 Arhenius, “Presentation Speech,” 479.
Lorentz’s stance on relativity as “irreproachable” and was also an admirer of Poincaré’s philosophy of science.

Bergson lauded Poincaré as the main representative of a French tradition in which “mathematicians wrote the philosophy of their science, and even of science in general,” and showed the “symbolic and provisional character” of scientific knowledge. He sided with Poincaré in having “a strong repugnance toward a philosophy that wants to explain all reality mechanically.” Bergson included in this camp prominent psychologists (Théodule Ribot, Pierre Janet, Alfred Binet, Georges Dumas) and sociologists (Émile Durkheim and Lucien Lévy-Bruhl) who held implicitly mechanistic, reductionist, and materialistic stances. Bergson’s critique influenced generations of thinkers seeking to investigate the role played by convention, choice, convenience, and epistemology in the selection and construction of theories and even, crucially, the role of science-fiction literature and popularization.

From Husserl to Heidegger

German philosophers often focused on some of the same themes raised by Bergson (characteristic of vitalism and Lebensphilosophie) in their assessments of relativity. While Bergson tackled the particular interpretation of observed results and formulae, Husserl’s critique of relativity was incorporated into the general framework of phenomenology. In 1935, during a Vienna lecture, he enumerated problems facing science, blaming Einstein for some of them. Einstein’s revolution had resulted in the distancing of science from those aspects that had “meaning” for us, mainly our everyday sense of time flowing:

Einstein’s revolutionary innovations concern the formulae through which the idealized and naively objectified physis is dealt with. But how formulae in general, how mathematical objectification in general, receive meaning . . . – of this we learn nothing; and thus Einstein does not reform the space and time in which our vital life runs its course.

A year later, in The Crisis of European Sciences and Transcendental Phenomenology: An Introduction to Phenomenological Philosophy, one of his most influential texts

74 Bergson to V. Norström, April 12, 1910, 350.
about science that was foundational for philosophers to come, he provided a particular interpretation of Einstein’s theory of relativity in relation to Michelson’s experiment. While “Einstein [used] Michelson experiments” to reach his conclusions, he used them in a particularly delimited way.76 One could envision researchers taking more aspects of science into consideration: “There is no doubt that everything that enters here – the persons, the apparatus, the room of the institute, etc. – can itself become a subject of investigation in the usual sense of objective inquiry, that of the positive science.”77 But there were good reasons why these additional topics should and did not matter to scientists. “Einstein,” he explained, “could make no use whatever of the theoretical psychological-psychophysical construction of the objective being of Mr. Michelson.” These boundaries, necessary for scientific work, arose from “pre-scientific” “presuppositions” that were “common to all” and arose from “the world of experience.” Offering to investigate the “premises” of scientific knowledge, he left its results and conclusions untouched.78

Similarly, in his early work, Heidegger did not argue for or against the merits of Einstein’s theory, stressing instead the need to think about “the problem of the measurement of time as treated in the theory of relativity.”79 Measurement could not simply give answers about time, since it itself occurred in time. The “temporal meaning of measurement” itself had to be considered, and it had to be considered first, before anything else, since it was more basic and more essential than any derivative scientific results. Heidegger’s lecture “The Concept of Time” diagnosed a damaging divide in the two dominant ways of thinking about time: the scientific notion of time and the lived notion. In this short lecture, Heidegger explained how a renewed interest in the concept of time was largely due to Einstein.

The physicist, argued Heidegger, used clock time. And clock time, he repeated, was a grossly inadequate concept for understanding time: “Once time has been defined as clock time then there is no hope of ever arriving at its original meaning again,” he warned.80 Heidegger’s “The History of the

77 Husserl, The Crisis of European Sciences and Transcendental Phenomenology, 125.
78 Husserl, The Crisis of European Sciences and Transcendental Phenomenology, 126.
Concept of Time” was motivated by “the present crisis of the sciences,” which, like Husserl, he blamed largely on Einstein.81 Although Heidegger was a Nazi sympathizer and at times enthusiast, his philosophy of science differed greatly from the standard fare of Deutsche Physik or Nazi racial science.82 Initially, Heidegger’s critique of Einstein was similar to that of Bergson and Husserl, but he soon distanced himself from their approaches by rejecting purely subjective notions of lived time as much as objective ones.

*Being and Time* (1927) sketched a new relation of philosophy to science, and of both to rational discourse and logical structure. “As regards the title ‘Being and Time,’ ‘time’ means neither the calculated time of the ‘clock,’ nor ‘lived time’ in the sense of Bergson and others,” he wrote. Heidegger contested an Aristotelian notion of temporality from which (in his view) derived Einstein’s notion of time. It represented the culmination of a denial of differences between past and future, left and right, or up and down, and so on. In “everydayness,” he argued, these differences mattered substantially. His focus on eyeglasses, radio, telephone, trains, and streets introduced a host of objects that had traditionally been left out from accounts of technology based largely on the machines of the Industrial Revolution. His later analysis of dictation, typewriters, the printing press, and paper represented the beginning of a media history *avant la lettre* by focusing on the sources of support and materiality of ratiocination itself.

Heidegger’s philosophy of technology and science rejected the common understanding of technology as a tool or as a machine. His perspective left no room for the politicization of science in terms of its supposed usefulness to the state that was part of the reductive biology of Nazi “scientific” racism and eugenics, nor did he fall into line with the denigration of theoretical physics and an exaltation of the experimental and technological that was typical amongst critics of Einstein. He also differed from most right-wing or left-wing scientists, artists, and intellectuals whose focus on technology was either of effusive celebration or reactionary rejection: “The much discussed question of whether technology makes man its slave or whether man will be able to be the master of technology is already a superficial question.” In arguing against common views that considered that “technology” and ‘man’ were two ‘masses,’’ he not only unsettled the understanding of both,

but called into question the typical “anthropological” conceptualization of the human as *homo faber* and *homo sapiens*.  

**Quantum Mechanics**

The conflict between relativity and quantum mechanics intensified with the political tensions of the time. Although historians have attempted to draw strict parallels between these fields and particular political stances (identifying the indeterminism of quantum mechanics with the irrationalism of German *Kultur*), these associations break down upon close analysis.  

The conflict between a quantum-mechanical description of the world and a relativistic one was articulated clearly during a discussion between Bohr and Einstein at the Fifth Solvay International Conference (1927). The discussion revived with renewed force questions about the role of philosophy and epistemology in science. “This epistemology-soaked orgy out to burn itself out,” Einstein insisted to Schrödinger. Relativity theory, during these years, ran the risk of appearing conservative and retrograde. “No doubt, however, you smile at me and think that, after all, many a young whore turns into an old praying sister, and many a young revolutionary becomes an old reactionary,” wrote Einstein to Schrödinger. Rather than be forced to rethink our common understanding of physical reality, Einstein would insist that quantum mechanics was incomplete. Others, led by David Bohm, would argue for the existence of “hidden variables” that could revert the theory’s ostensible indeterminism back to traditional determinism.  

The discussions between Einstein and quantum physicists brought to light the question of how general beliefs and even religious ones affected science. Bohr denounced Einstein’s now famous remark – “God does not play dice with the universe” – worrying that “utterances of this kind would naturally in many minds evoke the impression of an underlying mysticism foreign to the spirit of science.”  

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The lack of public understanding and the “mystical” tenor of scientific discourse concerned the highest echelons of the intellectual elites of the 1930s. In 1938 the International Commission for Intellectual Cooperation under the auspices of the League of Nations tried to moderate the conflict during a meeting in Warsaw, but these efforts broke down as tensions across Europe intensified.

Postwar Continental Thought

Public accounts of the development of the atomic bomb affected the way in which many intellectuals thought of the relation of physics to general culture. Most accounts of its development stressed the role of Einstein, Robert Oppenheimer, and theoretical physicists rather than chemistry and industrial engineering, placing it within a narrative of scientific rather than military innovation. Censorship about the science of radioactivity and the industrial chemistry work necessary for uranium-isotope isolation contributed to the attribution of an exaggerated importance to physics and even to relativity theory.  

While relativity theory was credited with “saving lives,” the atomic bomb’s destructive power could not be ignored.

In the post-World War II years the negative consequences of science were explored by Max Horkheimer and the Frankfurt School, who saw them as arising mainly from an over-specialized “instrumental rationality” that led scientists, especially those working on the applied sciences, to ignore the broader meaning of their work and neglect their social responsibility.

Heidegger attempted a different approach, setting himself apart from the critiques of instrumental reason of the Frankfurt School, by inquiring into the “essence” of technology and questioning the concept of instrumentality itself. Following the work of Heisenberg on quantum mechanics closely, he introduced a critique of theories of causality into his philosophy of technology, leading him to a different understanding of the concept of instrumentality itself. By reference to Heisenberg, he considered a common conception of instrumentality as tied to particular causal forms of reasoning and urged his listeners to question these links in order to gain a better understanding of the

failure to control our destiny in relation to things in general. "So long as we
do not allow ourselves to go into these questions, causality and with it
instrumentality, and with the latter the accepted definition of technology,
remain obscure and groundless."\(^{90}\) In the context of these investigations, he
was heard drawing offensive parallels between concentration camps and
modernized agriculture (in an unpublished lecture given in Bremen on December 1, 1949).\(^{91}\) In the published version of these lectures, Heidegger described connections between different technologies in terms of an “essence” that was neither causal nor moral, placing mundane technolo-
gies next to “demonic” ones.

“Das Ding” placed the atomic bomb and the hydrogen bomb next to radio
and film, arguing for the need to think of them by reference to a simple
ceramic jug (and the table and bench on which it may be placed) as part of his
continuing effort to understand the mundane next to the “terrifying,” and the
new next to the ancient, in his attempts to change our common understand-
ing of technology and “instrumental” reason. Rejecting accounts based
on the use of technology (and the morality thereof), he strove to get at
a deeper ethical structure of the thinking processes themselves that gave rise
to an understanding of our environment as “instrumental” in the first place.

“The Question Concerning Technology” concerned itself with atomic
energy, radar, hydroelectric power, the mechanized food industry, airliners,
paper, magazines, and cyclotrons (among other things) to define an “essence”
cutting across all these systems. In What Is Called Thinking?, the first post-
World War II university lectures Heidegger gave to students and the last ones
before his retirement, one can see Heidegger attempting to ground logic and
thinking in post-Kantian terms by considering thinking in relation to memory
and thankfulness.\(^{92}\)

In France, discussions about modern physics by prominent intellectuals
often discussed the perils of unbridled “rationality” and continued to draw on
themes about Einstein’s role as a public intellectual. Maurice Merleau-Ponty’s
“Einstein and the Crisis of Reason” centered on how an all-pervading scientism
had overtaken experience: “The experience of the perceived world with its
obvious facts is no more than a stutter which precedes the clear speech of
science.” Merleau-Ponty questioned the common deference of most

\(^{90}\) Martin Heidegger, “The Question Concerning Technology,” in The Question Concerning

\(^{91}\) Quoted in Philippe Lacoue-Labarthe, Heidegger, Art, and Politics, trans. Chris Turner
(Oxford: Blackwell, 1990), 34.

Row, 1968).
intellectuals toward physics and physicists and how they were consulted as authorities about everything from the arts to government: “And since it was precisely Einstein who showed that at a great distance a present is contemporaneous with the future, why not ask him the questions which were asked of the Pythian oracle?”

Roland Barthes in “The Brain of Einstein” (originally 1956) covered some similar themes:

Einstein fulfills all the conditions of myth . . . at once magician and machine, eternal researcher and unfulfilled discoverer, unleashing the best and the worst, brain and conscience, Einstein embodies the most contradictory dreams, and mythically reconciles the infinite power of man over nature with the “fatality” of the sacrosanct, which man cannot yet do without.

Gilles Deleuze also rethought the relation of science to philosophy in relation to Einstein and Bergson, outlining two possible ways for philosophy to interact with science. In one instance “philosophy can renounce its rivalry with science, can leave things to science and present itself solely in a critical manner, as a reflection.” In the alternative case, philosophy competed against science as an alternative form of knowledge, seeking “to establish, or rather restore, another relationship to things, and therefore another knowledge, a knowledge and a relationship that precisely science hides from us, of which it deprives us.” With some notable exceptions, the work of most post-World War II intellectuals fell into these either–or camps, as they were no longer able to imagine a form of knowledge that affected philosophy, science, and general culture simultaneously.

Like other intellectuals at the time, and in stark contrast to logical positivists and analytical philosophers, continental thinkers such as Deleuze and Barthes argued against the benefits (and even possibility) of separating science from other areas of general culture and against setting it aside as a privileged form of knowledge. Gaston Bachelard, for the anniversary of Einstein’s seventieth birthday, revived questions about the relation of relativity theory to the stories through which it was popularized, asking the following question: “All the tales of passing trains which signal an observer standing in a station, of aviators who smoke cigars in lengthened or

contracted periods of time – to what purpose are they?” He argued against the usual science-popularization explanation, where they were considered to be made for “those who have not understood” and considered them instead as an essential part of a broader reconfiguration of a “space-time notion” that could not be limited to specialized science. In addition, he asked readers to accept paradoxical aspects of science (such as the presence of the concrete in the abstract and the abstract in the concrete) as essential, even when these did not fit within traditional divisions between science and the humanities, or between scientific and poetic truth.

From Quine to Kuhn

Particular insights of late-nineteenth- and early-twentieth-century Francophone philosophy were revived by post-World War II Anglophone philosophers. The “Duhem–Quine thesis,” which combined some of the insights of W. V. O. Quine with those of Duhem, became a powerful anti-logical positivist argument for the need to consider how theoretical presuppositions could not be completely eliminated from scientific descriptions of the world.96

Kuhn’s Structure of Scientific Revolutions (first published in 1962 as part of the Foundations of the Unity of Science series) can be considered as marking the end of an era characterized by a particular understanding of science. While part of Kuhn’s analysis was based on insights from applied experimental psychology (the inverted goggle experiments of the Hanover Institute), much of the discussion around it centered on its repercussions for a more general conception of knowledge bounded by “paradigms,” a term closely related to the terms “worldview” (Weltanschauung) and “conceptual structure” (Begriffssystem) that had been widely used by relativity and quantum physicists to describe their new theories. By considering key episodes in the history of science as involving paradigm shifts, Kuhn’s account closely followed a model associated with the work of Alexandre Koyré and the “history of ideas” movement. Yet his historical recounting of theory choice during periods of revolution was most similar to Poincaré’s. When exploring the Copernican case, he claimed that “available observational tests ... provided no basis for a choice between them [Ptolemy and Copernicus].”97

Much earlier, at the Congrès International de Philosophie of 1900, Poincaré

had framed Copernicus’s revolution as nothing more than a more convenient formulation than the preceding ones.  

The Social Studies of Knowledge (SSK) movement of the late 1970s and 1980s responded to the “sociology of knowledge” movement of Merton and his school by incorporating a more subtle understanding (partly inspired by Michel Foucault) of the category of “the political” in science as embodied in subtle intersubjective power relations. For the most part, SSK practitioners stressed the primacy of theory and even language in comparison with the value of observations, borrowing as well from the “linguistic turn” affecting philosophy more generally. Some of these insights, which were often introduced as a corrective to the “naïve realism” of the logical positivists, were associated with “postmodernity” and “French theory.”

Even as intellectuals, historians, and philosophers continued to develop novel accounts about science and technology, the trauma from Nazi critiques of relativity theory in modern physics continued to mark modern European thought. For Jürgen Habermas, overt interference with the processes of consensual scientific deliberation was clearly and simply identified as the process that had led to the “freak of a [German] natural physics.”

The importance of detailed and careful historical and philosophical accounts of actual scientific practices, instruments, experiments, and debates paled in comparison with these world historical events.

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