

Weimar Culture, Causality, and Quantum Theory, 1918–1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment

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“It is interesting to observe that even physics, a discipline rigorously bound to the results of experiment, is led into paths which run perfectly parallel to the paths of the intellectual movements in other areas [of modern life].” Gustav Mie, inaugural lecture as Professor of Physics, University of Freiburg i.B., 26 January 1925.

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In perhaps the most original and suggestive section of his book on *The Conceptual Development of Quantum Mechanics* Max Jammer contended "that certain philosophical ideas of the late nineteenth century not only prepared the intellectual climate for, but contributed decisively to, the formation of the new conceptions of the modern quantum theory"¹; specifically, "contingentism, existentialism, pragmatism, and logical empiricism, rose in reaction to traditional rationalism and conventional metaphysics. . . . Their affirmation of a concrete conception of life and their rejection of an abstract intellectualism culminated in their doctrine of free will, their denial of mechanical determinism or of metaphysical causality. United in rejecting causality though on different grounds, these currents of thought prepared, so to speak, the philosophical background for modern quantum mechanics. They contributed with suggestions to the formative stage of the new conceptual scheme and subsequently promoted its acceptance."²

These are far-reaching propositions. Properly construed they are,

1. M. Jammer, *The Conceptual Development of Quantum Mechanics* (New York: McGraw-Hill, 1966), section 4.2, "The Philosophical Background of Non-classical Interpretations"; on pp. 166-167.

2. *Ibid.*, p. 180. The search for philosophic precedents and influences has otherwise focused almost exclusively upon Bohr's doctrine of complementarity. This issue, which I am not directly concerned with here, has been recently examined once again and the literature reviewed by Gerald Holton, "The Roots of Complementarity," *Daedalus*, 99 (Fall, 1970), 1015-1055.

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I think, essentially correct. But it must be said that Jammer did not go very far toward demonstrating them. He displayed such anticausal sentiments among a variety of late nineteenth-century philosophers—French, Danish, and American—but adduced scarcely any evidence to bridge the wide gaps of a quarter century of time, a cultural tradition, and the disciplines of philosophy and physics, which separated their philosophical theses from the development of quantum mechanics by German-speaking Central-European physicists circa 1925. It is not my aim to fill in these gaps, but rather to examine closely the lay of the land on the far side of them. The result is, on the one hand, overwhelming evidence that in the years after the end of the First World War but before the development of an acausal quantum mechanics, under the influence of “currents of thought,” large numbers of German physicists, for reasons only incidentally related to developments in their own discipline, distanced themselves from, or explicitly repudiated, causality in physics.

Thus the most important of Jammer’s theses—that extrinsic influences led physicists to ardently hope for, actively search for, and willingly embrace an acausal quantum mechanics—is here demonstrated for, but only for, the German cultural sphere. This cultural qualification is essential; it forms the basis of my attempt to provide, on the other hand, an answer to the question—in its general form crucial to all intellectual history—why and how these “currents of thought,” evidently of negligible effect upon physicists at the turn of the century, came to exert so strong an influence upon German physicists after 1918. For it seems to me that the historian cannot rest content with vague and equivocal expressions like “prepared the intellectual climate for,” or “prepared, so to speak, the philosophical background for,” but must insist upon a causal analysis, showing the circumstances under which, and the interactions through which, scientific men are swept up by intellectual currents.

Such an analysis may be either “psychological” or “sociological.” That is, it may either consider the mental makeup of the individual scientists concerned, stressing previous intellectual environments and conditioning experiences as determinative of present attitudes, or, on the contrary, it may ignore these factors, treating present mental posture as socially determined response to the immediate intellectual environment and current experiences. I have chosen the latter

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course, and sought a model in which certain "field variables" and their derivatives at a given place and time are regarded as evoking corresponding attitudes. Though it may seem harsh to stress the social pressure and ignore the emotional pain, though it may seem unsatisfactory to break off our explanatory endeavors at the level of the individual decision, nonetheless I do think the "sociological" the more general and fruitful approach.

The inquiry must begin, then, by characterizing the intellectual milieu in which the German physicists were working and quantum mechanics was developed. This is a formidable problem, above all on account of methodologic difficulties. And the task is especially unattractive to the historian of science, for it obliges him to deal with the "expressions" of nonscientists as well as those of scientists, thus forcing the abandonment of the demarcation criterion by which he seeks to identify and delimit his subject. Nevertheless, with aid and guidance from previous studies by general intellectual historians, especially the work of Fritz K. Ringer, I have addressed this problem in Part I. I show that in the aftermath of Germany's defeat the dominant intellectual tendency in the Weimar academic world was a neo-romantic, existentialist "philosophy of life," reveling in crises and characterized by antagonism toward analytical rationality generally and toward the exact sciences and their technical applications particularly. Implicitly or explicitly, the scientist was the whipping boy of the incessant exhortations to spiritual renewal, while the concept—or the mere word—"causality" symbolized all that was odious in the scientific enterprise.

Now if, as is largely the case even at this late date, the interest of the historian of science is held exclusively by the substantive scientific achievements, he will immediately be struck by a remarkable paradox: this place and period of deep hostility to physics and mathematics was also one of the most creative in the entire history of these enterprises. Faced with this paradox many of us would be tempted to rub our hands with satisfaction, to regard it a welcome refutation of any attempt to impugn the autonomy of these sciences and the sufficiency of intellectualist-internalist history of them. But such an inference would be too hasty. Presupposing the hostility of the intellectual environment, the crucial question is the *nature* of the response of the exact scientists to this circumstance. I had myself previously assumed that in the face of antiscientific currents the pre-

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dominant response in these highly professionalized sciences would be retrenchment, withdrawal into the science and the community of its practitioners, reaffirmation of the discipline's traditional ideology—i.e., its notion of the value, function, motive, goal, and future of scientific activity.³ Were that the case, then, a fortiori, any attempt to attribute a strong and direct influence of that same intellectual environment upon the scientific discourse and dispositions of these same men would appear implausible.

Yet the historian who takes even the most casual notice of the valuations of physical science in contemporary American society, on the one hand, and the present ideological tendencies in these sciences, on the other hand, could scarcely maintain that the predominant response to a hostile intellectual environment is retrenchment. On the contrary, as sentiments of resentment and antagonism toward the scientific enterprise—coupled with a revival of existentialist *Lebensphilosophie*—have become prominent in the last few years, so also have the expressions of and concessions to these same sentiments within the sciences themselves. We are indeed witnessing in America today a widespread and far-reaching accommodation of scientific ideology to a hostile intellectual milieu. As the distinguished physical chemist Franklin A. Long recently stated in both explanation and advocacy of this development: “Faculty, and especially students, are sensitive to social problems, are eager to work on them, and are often prepared to change their previous ways of life to do so. The pressures of discipline orientation and the tradition of individual scholarship are strong among faculty members, but not strong enough to counter the pressures of social concern.” And in all of this “responsiveness” there is an astonishing sincerity, a striking absence of cynical, calculated image projection, testifying to a surprising participation of the physical scientists themselves in those fundamentally, often manifestly, antiscientific sentiments.⁴

3. P. Forman, *The Environment and Practice of Atomic Physics in Weimar Germany* (Ph.D. dissertation, Berkeley, 1967; Ann Arbor: University Microfilms, 1968), pp. 11-24.

4. F. A. Long, “Interdisciplinary Problem-Oriented Research in the University [editorial],” *Science*, 171 (12 March 1971), 961. Marvin L. Goldberger, “Physics and Environment: How Physicists Can Contribute,” *Physics Today* (December 1970), 26-30, and the reply by John Boardman, *ibid.* (February 1971), 9. The new mood, especially the neo-Spenglerianism, in the scientific community is discussed by Bentley Glass in his presidential address to the AAAS, 28 December 1970, “Science: Endless Horizons or Golden Age?” *Science*, 171 (8 January 1971), 23-29.

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But our contemporary experience does not merely lead us to anticipate an ideological accommodation by the Weimar physicists and mathematicians; it also suggests a simple model for the circumstances under which such accommodation is likely to occur. We may suppose that when scientists and their enterprise are enjoying high prestige in their immediate (or otherwise most important) social environment, they are also relatively free to ignore the specific doctrines, sympathies, and antipathies which constitute the corresponding intellectual milieu. With approbation assured, they are free of external pressure, free to follow the internal pressure of the discipline—which usually means free to hold fast to traditional ideology and conceptual predispositions. When, however, scientists and their enterprise are experiencing a loss of prestige, they are impelled to take measures to counter that decline. Drawing upon Karl Hufbauer's factorization of prestige into image and values, one sees that such countermeasures will in general be attempts to alter the public image of science so as to bring that image back into consonance with the public's altered values. But if this is not mere image projection, then such alterations of the image of the scientist and his activity will also involve an alteration of the values and ideology of the science, and may even affect the doctrinal foundations of the discipline—as Theodore Brown has shown of the beleaguered College of Physicians in the latter seventeenth century.⁵

In Parts II and III, I apply this model to the German-speaking exact scientists working in academic environments in the Weimar period. Bearing in mind the radically rearranged scale of values ascendant in the aftermath of Germany's defeat, I explore in Part II the response of these scientific men at the ideological level. This response I have sought primarily in addresses by exact scientists to academically educated general audiences, and especially in their addresses to their assembled universities. The historian is fortunate that the institutions of German academic life provided frequent occasions for addresses before university convocations, and doubly fortunate that it was customary to publish such *Reden*. Conversely,

5. K. Hufbauer, "Social Support for Chemistry in Germany During the Eighteenth Century: How and Why Did It Change?" in this volume, pp. 205-231; T. M. Brown, "The College of Physicians and the Acceptance of Iatromechanism in England, 1665-1695," *Bulletin of the History of Medicine*, 44 (1970), 12-30.

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the existence of these institutions is both an index and an instrument of the extraordinarily heavy social pressure which the German academic environment could and did exert upon the individual scholar or scientist placed within it. As I illustrate in Part II, there was in fact a strong tendency among German physicists and mathematicians to reshape their own ideology toward congruence with the values and mood of that environment—a repudiation of positivist conceptions of the nature of science, of utilitarian justifications of the pursuit of science, and, in some cases, of the very possibility and value of the scientific enterprise.

Was the tendency toward accommodation, which predominated in the response of this highly professionalized scientific community to its hostile intellectual environment, confined to the ideological level, or did it extend beyond it into the substantive doctrinal content of the science itself? Specifically, are there indications that German physicists and mathematicians were anxious to, and deliberately tried to, alter the character of their disciplines as cognitive enterprises and to alter specific concepts employed within them in order to bring their sciences in closer conformity with the values of the Weimar intellectual milieu? I strongly suspect that the intuitionist movement in mathematics, which won so many adherents and created so much furor in Germany in this period, was primarily an expression of just such inclinations and aims. I am convinced, and in Part III endeavor to demonstrate, that the movement to dispense with causality in physics, which sprang up so suddenly and blossomed so luxuriantly in Germany after 1918, was primarily an effort by German physicists to adapt the content of their science to the values of their intellectual environment.

The explanation of the creativity of this place and period must therefore be sought, in part at least, in the very hostility of the Weimar intellectual milieu. The readiness, the anxiousness of the German physicists to reconstruct the foundations of their science is thus to be construed as a reaction to their negative prestige. Moreover the nature of that reconstruction was itself virtually dictated by the general intellectual environment: if the physicist were to improve his public image he had first and foremost to dispense with causality, with rigorous determinism, that most universally abhorred feature of the physical world picture. And this, of course, turned out

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to be precisely what was required for the solution of those problems in atomic physics which were then at the focus of the physicists' interest.

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I. WEIMAR CULTURE AS A HOSTILE INTELLECTUAL ENVIRONMENT

I.1. As Perceived by the Physicists and Mathematicians

Through the summer of 1918 the German physical scientists, like the rest of the German public, continued to look forward with confidence and satisfaction to a victorious conclusion of the war in which they had been engaged four years. They, perhaps more than any other segment of the German academic world, also felt *self-confidence* and *self-satisfaction* due to their contributions to Germany's military success and to their anticipation of a postwar political and intellectual environment highly favorable to the prosperity and progress of their disciplines. The botanist looking about his institute, bleak and vacant, had to conclude that "probably it will also remain so after the war, for youth will turn to technology and leave so 'unpractical' a discipline as botany lying by the wayside."⁶ The chemist, the physicist, the mathematician, however, emphasizing the great practical importance of their subjects during the war and the desirability and inevitability of still closer collaboration with technology in the future, looked forward to yet more, larger, and better stocked institutes and to substantially increased public

6. Karl v. Goebel to Th. Herzog, Munich 19 July 1917, in Goebel, *Ein deutsches Forscherleben in Briefen aus sechs Jahrzehnten, 1870-1932*, ed. Ernst Bergdolt, 2nd ed. (Berlin, 1940), p. 170.

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esteem and academic prestige. “The closer we appear to approach the victorious conclusion of the war,” Felix Klein observed in June 1918 before an audience including leaders of German industry and the Prussian government, “the more our thoughts are dominated by the question what, after peace is successfully won, ought then to come.” Klein’s desiderata ranged from a mathematical institute for himself and his university, through a general reorientation of academic research in the exact sciences to achieve a “preestablished harmony” with the requirements of industry and the military, to a corresponding reorientation of German education at all levels.⁷ And at least the first of these desiderata seemed assured as the Prussian Minister of Education, Friedrich Schmidt, came forward to announce a grant of 300,000 Mark. Who, participating in these festivities, could have foreseen that the Göttingen mathematical institute would not be built for another ten years, and then only with American money?⁸

When that “victorious end” which seemed imminent in the summer of 1918 turned suddenly to utter defeat in the fall, the exact scientists found themselves confronting a dramatically transformed scale of public values and thus a drastically altered valuation of their field. That, certainly, was their perception of the situation. Had we no explicit testimony to this effect, we could nonetheless infer it from the defensive tone of the talks given by exact scientists before the assembled faculties and students at academic convocations. While during the latter years of the war such speeches convey self-

7. F. Klein, “Festrede zum 20. Stiftungstage [22 June 1918] der Göttinger Vereinigung zur Förderung der Angewandten Physik und Mathematik,” *Jahresbericht der Deutschen Mathematiker-Vereinigung*, 27 (1918), Part I, pp. 217-228; on pp. 217, 219. As the philologists noted with some bitterness, during the war the scientists and mathematicians had raised substantially their demands upon secondary school curricula: Robert Neumann, “Politik und Schulreform,” *Monatschrift für höhere Schulen*, 18 (1919), 93-106, “Vortrag, gehalten im Berliner Philologen-Verein Februar 1918”; Friedrich Poske and R. von Hanstein, *Der naturwissenschaftliche Unterricht an den höheren Schulen*, Schriften des Deutschen Ausschusses für den mathematischen und naturwissenschaftlichen Unterricht, II. Folge, Heft 5 (Leipzig-Berlin, 1918).

8. *Jahresbericht der D. M.-V.*, 27 (1918), Part 2, p. 47. In 1926 the International Education Board of the Rockefeller Foundation appropriated \$275,000 for a mathematical institute. (Geo. W. Gray, *Education on an International Scale, A History of the International Education Board, 1923-1938* [New York, 1941], p. 30; Otto Neugebauer, “Über die Einrichtung des Mathematischen Institutes der Universität Göttingen,” *Minerva-Zeitschrift*, 4 [1928], 107-111.)

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assurance, confidence in the esteem and good will of the audience, in the Weimar period that is seldom the case. And while it is difficult to display this *tone*, one can at least point to passages alluding more or less explicitly to reproaches against exact science which the speaker clearly supposes to be in his audience's mind. Thus in November 1925 Wilhelm Wien described the great scientific discoveries of the early modern period, especially Newton's derivation of the motion of the planets from the laws of mechanics, as "the first convincing demonstration of the causality [n.b.] of natural processes which revealed to man for the first time the possibility of comprehending nature by the logical force of his intellect." But he then immediately conceded that this program, which the natural scientist finds so grand, has its limitations, and he proceeded to quote Schiller: "Without feeling even for its creator's honor/ Like the dead stroke of the pendulum clock/ Nature devoid of God follows knavishly the law of gravity."⁹ The quotation is clearly in response to popular demand, as the astrophysicist, Hans Rosenberg, makes still clearer in his academic address on 18 January 1930: "'Your subject is, to be sure, the most sublime in space/ But, friend, the sublime does not reside in space,' I hear Schiller-Goethe call out to us."¹⁰

It is, of course, their audience which Wien, Rosenberg, *et al.* hear calling out these sentiments, and they seek to escape half the reproach by showing that they are themselves at least familiar with the classical literary expressions of German idealism. When, however, the physicist or mathematician was in the audience he had to listen to far sharper reproaches. In March 1921, Friedrich Poske came away from the funeral of the poet Carl Hauptmann smarting at the accusations against the exact natural sciences which he encountered there,¹¹ accusations apparently much like those which poor Max

9. W. Wien, *Universalität und Einzelforschung. Rektorats-Antrittsrede, gehalten am 28. November 1925*, Münchener Universitätsreden, Heft 5 (Munich, 1926), 19 pp., on 14.

10. H. Rosenberg, *Die Entwicklung des räumlichen Weltbildes der Astronomie. Rede zur Reichsgründungsfeier . . . am 18. Januar 1930* (Kiel, 1930), 27 pp., on 26. The same lines are quoted—with a still deeper "bow before the secret which the other side hides from us"—by Hans Kienle, "Vom Wesen astronomischer Forschung. Rede, gehalten bei der Verfassungsfeier der Universität Göttingen am 29. Juli 1932," *Bremer Beiträge zur Naturwissenschaft*, 1 (1933), 113-125, on 125.

11. F. Poske at the Hauptversammlung of the Deutscher Verein zur Förderung des mathematischen und naturwissenschaftlichen Unterrichtes, 31 March 1921. (*Unterrichtsblätter für Mathematik und Naturwissenschaft*, 27 [1921], 34.)

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Born had to listen to daily from his wife, a would-be poet and playwright. Hedwig Born derived a masochistic pleasure from “the feeling of being cast upon an icy lunar landscape” which the company of “objective” natural scientists aroused in her.¹² Nor did she hesitate to let her husband’s colleagues know that “it is always like a revelation to me whenever behind the *physicist* I suddenly discover the human being; there are, I mean, also inhuman physicists.”¹³ Certainly there is no reason to think that Einstein’s explanation—“what you call ‘Max’s materialism’ is simply the causal [n.b.] mode of considering things”—alleviated Mrs. Born’s disquiet.¹⁴

Painful as it may have been for the theoretical physicist to have to live with such attitudes, the accusation of *Entseelung*, of destruction of the soul, of the world was not the worst he encountered. As Max von Laue saw it in the summer of 1922, the school of Rudolf Steiner “raises the most serious charges against today’s natural science. It is represented as bearing the guilt for the world crisis [n.b.] in which we stand at present, and the whole of the intellectual and material misery bound up with that crisis is charged to natural science’s account.”¹⁵ The counterattack which Laue published was read “with much pleasure” by his mentor and colleague Max Planck, who thought it “will certainly achieve good effects in wider circles.”¹⁶

12. H. Born, “Albert Einstein ganz privat,” *Helle Zeit—dunkle Zeit. In memoriam Albert Einstein*, ed. C. Seelig (Zurich, 1956), pp. 35–39, on 36.

13. H. Born to H. A. Kramers, 29 September 1925: “Offengestanden hatte ich früher fast etwas Angst vor Ihnen! Aber die ist ganz verschwunden, seit ich hier die Wärme, den Ernst und die ungekünstelte Kraft Ihres Wesens kennen lernen durfte. Es ist mir immer wie eine Offenbarung, wenn ich neben dem *Physiker* plötzlich den Menschen finde; es gibt nämlich auch unmenschliche Physiker!” (Archive for History of Quantum Physics, Sources for History of Quantum Physics Microfilm 8, Section 2; for descriptions and locations of this archive, see Thomas S. Kuhn, *et al.*, *Sources for History of Quantum Physics. An Inventory and Report*, Memoirs of the American Philosophical Society, Vol. 68 [Philadelphia, 1967].)

14. Einstein to H. Born, 1 September 1919, in Albert Einstein, Hedwig and Max Born, *Briefwechsel, 1916–1955*, edited and annotated by M. Born (Munich, 1969), p. 32. An English translation is being published.

15. M. v. Laue, “Steiner und die Naturwissenschaft,” *Deutsche Revue*, 47 (1922), 41–49; reprinted in Laue’s *Aufsätze und Vorträge = Gesammelte Schriften und Vorträge*, Band III (Braunschweig, 1962), pp. 48–56, on 48.

16. Planck to Laue, 8 July 1922: “Ihren Aufsatz über R. Steiner habe ich mit vielem Vergnügen gelesen. Er . . . wird gewiss in weiteren Kreisen gute Wirkung erzielen.” (Handschriftensammlung, Bibliothek, Deutsches Museum, Munich.)

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Clearly Planck saw Rudolf Steiner as merely providing the occasion and the ostensible target for rebutting a set of attitudes which he and Laue felt to be widespread among the German educated public. Planck himself adverted to these attitudes and to their danger for science in an address in the Prussian Academy of Sciences a few weeks later.¹⁷ Early in the following year he complained bitterly in a public lecture that “precisely in our age, which plumes itself so highly on its progressiveness, the belief in miracles in the most various forms—occultism, spiritualism, theosophy, and all the numerous shadings, however they may be called—penetrates wide circles of the public, educated and uneducated, more mischievously than ever, despite the stubborn defensive efforts directed against it from the scientific side.” Compared to this movement, the agitation of Planck’s former *bête noir*, the Monist League, has had, he now allows, “only very meagre success.”¹⁸

It is thus not surprising that the remnants of this largely defunct positivist-monist movement thoroughly agreed with Planck that the Weimar intellectual environment was fundamentally and explicitly antagonistic to science. Drawing upon the universally accepted analogy between contemporary Germany and the period following its defeat by Napoleon, Wilhelm Ostwald thought it evident that “In Germany today we suffer again from a rampant mysticism,

17. M. Planck, “Ansprache des vorsitzenden Sekretärs, gehalten in der öffentlichen Sitzung zur Feier des Leibnizischen Jahrestages, 29. Juni 1922,” *Preuss. Akad. d. Wiss., Sitzungsber.* (1922), pp. lxxv-lxxvii, reprinted in *Max Planck in seinen Akademie-Ansprachen; Erinnerungsschrift der Deutschen Akademie der Wissenschaften zu Berlin* (Berlin, 1948), pp. 41-48. A similar characterization of the intellectual environment had been given in the fall of 1920 by Artur Schoenflies, *Über allgemeine Gesetzmässigkeiten des Geschehens* [Rektoratsantrittsrede], *Frankfurter Universitätsreden XI* (Frankfurt, 1920), 16 pp., on 4: “In increasing measure in recent [letzten] years there has developed a conscious hostility to the natural-scientific mode of thought. . . . The fact is that the new mode of thought with force and bluster has fought its way through to success in all fields—in *Wissenschaft* and art, literature and politics, in writing and speaking.”

18. M. Planck, *Kausalgesetz und Willensfreiheit. Öffentlicher Vortrag gehalten in der Preuss. Akad. d. Wiss. am 17. Februar 1923* (Berlin, 1923), 52 pp.; reprinted in Planck, *Vorträge und Erinnerungen* (Stuttgart, 1949), pp. 139-168; on 162-163. And again, eight years later, “It is astonishing how many people, particularly from educated circles . . . fall under the sway of these new religions, iridescent with every hue from the most confused mysticism on out to the crassest superstition.” (“*Wissenschaft und Glaube. Weihnachtsartikel vom Jahre 1930*,” *ibid.*, pp. 246-249; also quoted at length in Hans Hartmann, *Max Planck als Mensch und Denker* [1953; reprinted Frankfurt, 1964], pp. 52-55, on 52-53.)

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which, as at that time, turns against science and reason as its most dangerous enemies.”¹⁹ And even where, as with the theory of relativity, there was great public interest in particular results of physical research, that interest was never, to my knowledge, construed by the physicists as evidencing appreciation and approbation of their enterprise. Rather, it struck Einstein as “peculiarly ironical that many people believe that in the theory of relativity one may find support for the anti-rationalistic tendency of our days.”²⁰

Arnold Sommerfeld was thus clearly speaking for most of his colleagues when, responding to a request from the most prestigious of the South German monthlies for a contribution to a special number on astrology, he asked:

Doesn't it strike one as a monstrous anachronism that in the twentieth century a respected periodical sees itself compelled to solicit a discussion about astrology? That wide circles of the educated or half-educated public are attracted more by astrology than by astronomy? That in Munich probably more people get their living from astrology than are active in astronomy? Certainly in Germany this anachronism is based in part upon the misery of the present. The belief in a rational [vernünftig] world order was shaken by the way the war ended and the peace dictated; consequently one seeks salvation in an irrational [unvernünftig] world order. But the reason must lie deeper, for astrology, spiritualism, and Christian Science are flourishing among our enemies also. We are thus evidently confronted once again with a wave of irrationality and romanticism like that which a hundred years ago spread over Europe as a reaction against the rationalism of the eighteenth century and its tendency to make the solution of the riddle of the universe a little too easy. Even though I [wir] have no illusions about being able to hold back this wave by means of arguments based upon reason, nonetheless I [wir] want to throw myself decisively against it.²¹

19. W. Ostwald, *Lebenslinien. Eine Selbstbiographie* (Berlin, 1926-1927), 3, 442. And again, *ibid.*, 2, 309, “It is at present considered modern to speak all conceivable evil of the intellect.”

20. A. Einstein, *Vossische Zeitung*, 10 July 1921, as quoted by Siegfried Grundmann, “Der Deutsche Imperialismus, Einstein und die Relativitätstheorie (1914-1933),” *Relativitätstheorie und Weltanschauung* (Berlin, 1967), pp. 155-285, on 194.

21. A. Sommerfeld, “Über kosmische Strahlung,” *Südd. Monatshefte*, 24 (1927), 195-198; reprinted in Sommerfeld's *Gesammelte Schriften* (Braunschweig, 1968), 4, 580-583. Cf. Lewis M. Branscomb, Director of the U.S. National Bureau of Standards, *Science*, 171 (12 March 1971), 972: “Astrology is booming; there are three professional astrologers in this country for every astronomer.”

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Although the German physical scientists, regardless of their special discipline, agreed that irrationalism and mysticism were characteristic of the postwar mood, altogether it was the mathematicians and the theoretical physicists who, more than the experimental physicists or the chemists, felt themselves to be the particular objects of odium, both public and private. One cannot withhold a certain sympathy for the Nazi Theodor Vahlen as he confesses in 1923 before the assembled members of his university how “a friendly attitude toward mathematics is so rare that, if we run across it, it really strikes us as especially remarkable.”²² This feeling of facing an antagonistic environment, inside and outside the university, was so generally shared among mathematicians that Gerhard Hessenberg could appeal to it in trying to persuade the theoretical physicist Arnold Sommerfeld to take a course of action which would antagonize an experimental physicist (Friedrich Paschen) to whom Sommerfeld looked for much of his raw material: “But we poor scapegoats of mathematicians have gotten to hear so much evil about ourselves these days—behind our backs as well as to our faces—what difference does a little bit more or less make. . . .”²³ Indeed, these “antimatematical currents,” “this onslaught against mathematics” which sprang forth after the war seemed so strong and threatening that in 1920 the German mathematicians joined together in a defense organization, the Mathematischer Reichsverband, whose special task was to protect the position of mathematics in the schools.²⁴

22. Th. Vahlen, *Wert und Wesen der Mathematik. Festrede . . . am 15. V. 1923*, Greifswalder Universitätsreden 9 (Greifswald, 1923), 32 pp., on 1. And in this, if in nothing else, Konrad Knopp agreed with Vahlen: “We mathematicians . . . have not been able to obtain, or even merely to retain, the position in public life which mathematics merits.” (“Mathematik und Kultur, Ein Vortrag,” *Preussische Jahrbücher*, 211 [1928], 283-300, on 283.)

23. G. Hessenberg to A. Sommerfeld, 16 June 1922: “Wir armen Sündenböcke von Mathematikern aber haben in diesen Tagen so viel schlechtes, hintenherum, wie auch vorneherum, über uns zu hören bekommen, dass es uns auf ein bischen mehr oder weniger nicht ankommt; der Gerechte hat nun einmal viel zu leiden.” (Sources for History of Quantum Physics Microfilm 33, Section 1.)

24. Georg Hamel, as president, at the first general assembly of the Mathematischer Reichsverband, Jena, 23 September 1921, *Jahresbericht der Deutschen Mathematiker-Vereinigung*, 31 (1922), Part 2, p. 118. And again at the second general assembly, Leipzig, 22 September 1922, the *Arbeitsausschuss* stressed in its report that “With respect to its place and prestige [*Geltung*] in the schools, mathematics finds itself in a defensive position. The contemporary intellectual currents, directed against intellectualism and rationalism, are decidedly unfavorable to mathematics.” (*Ibid.*, 32 [1923], Part 2, pp. 11-12.)

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The result, then, of this first approach to the problem of establishing the tenor of the intellectual environment within which the Weimar physical scientists worked so productively is unambiguous: the environment was *perceived* by the physical scientists to be markedly hostile. Is it therefore necessary to carry our inquiry any further? One might, after all, argue that it is vain to ask whether these perceptions corresponded to “reality” and that moreover the answer would be of no consequence for the behavior of the physical scientists. Nonetheless the accuracy or inaccuracy of these perceptions is certainly an important datum about these men, a datum which is essential for any attempt to infer their perceptions, and the effects upon their science, of a given intellectual environment. For the purposes of this paper, moreover, it is important to go farther afield in exploring the attitudes toward physical science in Weimar Germany; we need a more detailed specification of those attitudes if we are to determine how far and in what sense the ideology and ideas of the physical scientists may be regarded as responses to their intellectual environment.

I.2. As Confirmed by Other Observers

Unequipped and disinclined to undertake an extensive independent exploration and reconstruction of the Weimar intellectual environment, I have turned to other observers—first intellectual historians, then contemporary observers—seeking their conclusions and their guidance.

For our period and theme there are studies by Georg Lukács,²⁵ Kurt Sontheimer,²⁶ Peter Gay,²⁷ and—most recent, detailed, and relevant—by Fritz Ringer.²⁸ While these intellectual historians are not specifically concerned with the attitudes toward exact science,

25. G. Lukács, *Die Zerstörung der Vernunft. Der Weg des Irrationalismus von Schelling zu Hitler* (Berlin, 1954).

26. K. Sontheimer, *Antidemokratisches Denken in der Weimarer Republik* (Munich, 1962).

27. P. Gay, *Weimar Culture: The Outsider as Insider* (New York, 1968). An only slightly abridged version, omitting however the extensive bibliography, appeared under the same title in Donald Fleming and Bernard Bailyn, eds., *The Intellectual Migration* (Cambridge, Mass., 1969), pp. 11-93.

28. F. K. Ringer, *The Decline of the German Mandarins. The German Academic Community, 1890-1933* (Cambridge, Mass.: Harvard University Press, 1969).

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their characterizations of the intellectual milieu do in fact bear directly upon this question. Especially Ringer's examination of academic ideology places before us many of the attitudes toward science which pervaded the Weimar academic world and directs us to many important sources. And despite the diversity of the personal-professional backgrounds, research methods, and ethical-political motivations of these intellectual historians, by and large they give us the same general picture of the Weimar intellectual milieu: rejection of reason as an epistemological instrument because inseparable from positivism-mechanism-materialism, and because, as fundamentally disintegrative, incapable of satisfying the "hunger for wholeness";²⁹ glorification of "life," intuition, unmediated and unanalyzed experience, with the immediate apprehension of values, and not the dissection of causal nexus, as the proper object of scholarly or scientific activity. This "life-philosophy," of which existentialism was but a variety, Lukács sees as "the dominant ideology of the entire imperialistic period in Germany. . . . In the postwar period virtually all of the widely read bourgeois *Weltanschauungsliteratur* is *lebensphilosophisch*."³⁰

With these studies by intellectual historians giving us some confidence that we are not going seriously astray, let us look a little more closely at certain of the programmatic slogans of this life philosophy as epitomized by contemporary observers of Weimar intellectual life. Such characterizations of the intellectual environment will, I think, not merely suggest, irresistibly, a valuation of the physical scientist, but will also force us to recognize the crucial role of the concept of causality.

Within a year of the end of the war these intellectual currents, now monopolizing the movement for educational reform, were flowing everywhere. Discussing "the social-pedagogic demand of the present" in 1920, Alfred Vierkandt could see clearly that "We are generally experiencing today a full rejection of positivism; we are experiencing a new need for unity, a synthetic tendency in all the world of learning [Wissenschaft]—a type of thinking [Eindenken] which primarily emphasizes the organic rather than the mechanical, the living instead of the dead, the concepts of value, purpose, and goal,

29. The phrase is Gay's, *op. cit.* (note 27).

30. Lukács, *op. cit.* (note 25), p. 318.

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instead of causality.”³¹ A sharper and more penetrating analysis of this call for a “revolution in science [Wissenschaft]” in the early Weimar period is that which Ernst Troeltsch published in 1921.³² Here causality appears over and over again as the pejorative term epitomizing the tendency in *Wissenschaft* which the new movement rejects: “The methods of these specialized scientific disciplines are those of causal explanation, of natural causality, of psychophysical, psychological, and sociological causality. It is the ultimate intellectualization of our attitude toward the world, the disenchantment of the world, and the path toward an unlimited approximation to a totally causal system [Gesamtkausalsystem] of things.”³³

Troeltsch, in common with many other observers, cites Henri Bergson as perhaps the most important—and the only non-German—source of the movement against “all suffocating determinism.” “A general sigh of relief follows almost audibly the ever stronger establishment of this system.”³⁴

If now we draw all that together, the freedom from positivistic causalism and determinism, the overcoming of neo-Kantian formalism, . . . the orientation toward immediate experience of unanalyzable but understandable cultural tendencies, . . . a new phenomenological platonism which through visions beholds and justifies norms and essences, then one has all elements of the *wissenschaftlichen* revolution in one's hands. . . . It is a neoromanticism as formerly in the *Sturm und Drang*.³⁵

31. A. Vierkant, *Die sozialpaedagogische Forderung der Gegenwart* (Berlin, 1920), p. 20, as quoted by F. K. Ringer, “The German Universities and the Crisis of Learning, 1918-1932” (Ph.D. diss., Harvard University, 1960), p. 145.

32. E. Troeltsch, “Die Revolution in der Wissenschaft,” *Schmoller's Jahrbuch (Jahrbuch für Gesetzgebung, Verwaltung . . .)*, 45 (1921), 1001-1030. Reprinted in Troeltsch's *Gesammelte Schriften*, Vol. 4: *Aufsätze zur Geistesgeschichte und Religionssoziologie*, ed. Hans Baron (Tübingen, 1925; reprinted 1961), pp. 653-677.

33. *Ibid.*, p. 1020. Cf. Max Weber, “Science as a Vocation [1919],” *From Max Weber: Essays in Sociology*, trans. and ed. H. H. Gerth and C. Wright Mills (1946; reprinted New York, 1958), p. 142: “And today? ‘Science as the way to nature’ would sound like blasphemy to youth. Today, youth proclaims the opposite: redemption from the intellectualism of science in order to return to one's own nature and therewith to nature in general.”

34. *Ibid.*, p. 1005.

35. *Ibid.*, p. 1007. Or again, “The peculiarity of German thought, in the form in which it is nowadays so much emphasized, both outside and inside Germany, is primarily derived from the Romantic Movement . . . a revolution, above all, against the whole of the mathematico-mechanical spirit of science in Western Europe . . .” (Troeltsch, “The Idea of Natural Law and Humanity in World

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These intellectual currents, whose sources lay in the prewar period, but which welled up immediately following Germany's defeat, continued to dominate the intellectual milieu in the mid-1920's as in the first years of the Weimar Republic. In 1927, Theodor Litt, reviewing contemporary philosophy and its influence upon the ideal of liberal education [Bildung], found *Lebensphilosophie* to be the strongest intellectual current. It was not a system, not a school, but a general tendency which is only to be defined by what it opposes: "On the one hand . . . the mechanism and determinism of a causal explanation which calculates everything in advance, makes everything comparable, dissolves everything into elements—on the other hand . . . the rationalism and formalism of a logical systematization which deduces everything, classifies everything, subjects everything to concepts."³⁶

Litt went on to point out again the often noticed parallel between the rise of *Lebensphilosophie* and the "victorious breakthrough of 'wholistic' convictions" in biology (neovitalism) and psychology (Gestaltism, etc.).³⁷ It is therefore of some interest to ask what impression a biologist-philosopher of these convictions received of the Weimar intellectual milieu. Eloquent in this connection is Hans

Politics [1922]," in Otto Gierke, *Natural Law and the Theory of Society, 1500-1800*, trans. E. Barker [Cambridge, 1934; reprinted Boston, 1957], pp. 201-222, on 210.) Troeltsch emphasized (*op. cit.* [note 32], pp. 1003-1004, 1028-1029), that this "Revolution in der Wissenschaft" was confined to the *Geisteswissenschaften*, that the revolutionary innovations in natural science had no clear *weltanschaulich* significance, and he insisted that the close connection of the natural sciences with technology would prevent their sloughing off rigorous methods, or backsliding into "Naturphilosophie" and dilettantism. But, one would ask Troeltsch, what if, under the influence of these same intellectual currents, the exact scientists should repudiate their connection with technology—as indeed they did. Could we then expect some parallel to the romantic physics of the early nineteenth century?

36. Th. Litt, *Die Philosophie der Gegenwart und ihr Einfluss auf das Bildungsideal*, 2nd ed. (Leipzig, 1927), pp. 32-33. Cf. Friedrich Meinecke, "Über Spengler's Geschichtsbetrachtung," *Wissen und Leben*, 16 (1923), 549-561, as reprinted in Meinecke's *Werke*, 4 (Stuttgart, 1959), 181-195, characterizing the mood of the times: "One is also tired of having only interconnections of cause and effect [Ursache und Wirkung] demonstrated over and over again according to rational methods of cognition, and tired of performing such demonstrations oneself; one is of the opinion that there is a great deal more in life and humanity than an apparatus of mechanical causality [Kausalitäten]. One has become tired of knowing and thirsty for living. . . ."

37. Litt, *loc. cit.*

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Driesch's introduction to *Man and the Universe* (1928); for despite his vitalism, wholism, and idealism he too felt the milieu to be hostile to science and reason. Recognizing that it is "unfashionable" to take account of the results of natural science and that he will be put down as betraying his origin as a scientist, he nonetheless accepts the characterization of his method by the opprobrious epithet "rational" and holds that "the modern contempt for [natural] science is due to the fact that its champions take the concept in too narrow a sense, namely, as denoting a mechanistic view of the world."³⁸

The historian of science may feel impelled to object that it is a most serious misconception to regard physics after 1900 as "mechanistic," and that it is a complete misunderstanding of positivism to equate it with mechanism, materialism, or even rationalism. Indeed it is difficult to understand how contemporary observers generally failed to recognize in Mach, Ostwald, and their cohorts a quasi-romantic movement parallel in several respects to *Lebensphilosophie*.³⁹ But all such objections are, of course, entirely beside the point. The relevant question is only what image the educated public held of the physical scientist and his world view. The image of the mechanistic, rationalistic causalist led inevitably to a negative valuation.

I.3. Intellectual Allies: Vienna Circle and Bauhaus

But can this picture of the physical scientist's intellectual milieu be accurate? When we say "Weimar culture" do we not immediately think also of the Vienna Circle and logical positivism, of the Bauhaus and functionalism, as its typical expressions? And were not *these* movements inherently congenial to rational analysis and the achievements of modern physical science and technology?

Assuredly the Vienna Circle, with its goal of a "wissenschaftliche

38. H. Driesch, *Der Mensch und die Welt* (Leipzig, 1928), trans. by W. J. Johnson as *Man and the Universe* (London, 1929), pp. 5-8. Cf. Karl Jaspers, *Die geistige Situation der Gegenwart* (Berlin-Leipzig, 1932), trans. by E. and C. Paul as *Man in the Modern Age* (New York, 1933), p. 159: "Anti-science stalks abroad today amid all parties and sects and manifests its influence among persons of the most diversified outlooks, pulverizing the very substance of rational human existence."

39. Stephen G. Brush, "Thermodynamics and History," *The Graduate Journal*, 7 (1967), 477-565, on 530.

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Weltauffassung' based upon empiricism and logical atomistic analysis of conceptual structures, had a very "positive" attitude toward the physical sciences and mathematics. But how characteristic was their brand of philosophy? We are sometimes led to believe that logical positivism, which in fact emerged as a coherent program only in 1929/30, was the dominant current in German philosophy throughout the 1920's. Thus H. Stuart Hughes has the movement in full flower by the early 1920's and represents Ludwig Wittgenstein's *Tractatus Logico-Philosophicus*, of which the German edition (1921) lay virtually unread in the final number of Ostwald's defunct *Annalen der Naturphilosophie*, as "the most influential philosophical work of the post-war years. . . . [T]he neo-positivists . . . were able to rehabilitate the scientific method in philosophy . . . and for another two decades Europe was to be without a philosophy that could speak to the ordinary citizen. . . ."40

One need, however, only glance at the manifestos of the Vienna Circle in order to recognize that Hughes has utterly misrepresented the case. In *Wissenschaftliche Weltauffassung: Der Wiener Kreis*, the brochure with which in 1929 the circle first came before the public, "their tone," as Ringer rightly points out, "was that of exasperated outsiders."⁴¹ Indeed the opening lines tell us: "Many assert that metaphysical and theologizing thinking, not only in everyday life, but also in science and scholarship [in der Wissenschaft], are today again increasing. . . . The assertion itself is easily confirmed by a glance at the themes of lectures at the universities

40. H. S. Hughes, *Consciousness and Society. The Reorientation of European Social Thought, 1890-1930* (New York, 1958; reprinted New York, n.d.), pp. 399-401. Before we accept as fact that the "ordinary citizen" was deserted by philosophy we should hear what Heinrich Rickert had to say on this score in 1920: "The concept which today dominates the general intellectual atmosphere [die Durchschnittsmeinungen] in an especially high degree seems to us to be best designated by the expression *life*. For some time now it has become ever more frequently used, and plays a great role not only among the popular writers, but also among academic philosophers. 'Erlebnis' and 'lebendig' are favorite words, and there is no opinion which is counted so modern as that it is the task of philosophy to give a doctrine of life, which, shaping itself vitally and genuinely out of experience, is capable of being used by the living human being." (*Die Philosophie des Lebens. Darstellung und Kritik der philosophischen Modeströmungen unserer Zeit*. [Tübingen, 1920], p. 4.)

41. Ringer, *op. cit.* (note 28), p. 308.

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and at the titles of philosophical publications.”⁴² Writing in 1931 for their *Schriften zur Wissenschaftlichen Weltauffassung*, Philipp Frank, the one professional physicist in the group, repeatedly cited and quoted the “Ganzheitsphilosophie” of Othmar Spann’s *Kategorienlehre* (1924) as characteristic of the negative valuation of natural science and mathematics in the prevalent “school philosophy.”

To the discipline which depicts things by means of merely external (quantitative) features the essence of things remains eternally foreign. This is the key to why mathematical-causal natural science is not a comprehending, mentally creative discipline as the *Geisteswissenschaften* are. . . . The quantifying, so-called exact, investigation is on the contrary merely measurement and, since it ignores the essence of things and must decompose them into magnitudes in order to inventory them, it does not deserve the name *Wissenschaft* in the same high sense as the *Geisteswissenschaften*. . . . The question of utility and achieved goals is one thing, the worth [Würde] of genuine *Wissenschaften* concerned with totality and essence is another. Such worth modern mathematical natural science does not possess today.⁴³

Far from dominating German philosophy in the 1920’s, the Vienna Circle and the corresponding group in Berlin—the *Gesellschaft für empirische Philosophie* around Hans Reichenbach and Richard von Mises—with their high positive valuation of mathematical natural science represented a rather late and distinctly marginal movement. The impression which in 1929 Sidney Hook brought back to the United States from a year of philosophical study in Germany was that almost all the contemporary schools “are amazingly indifferent to the methods and results of modern physical science.” Worse, “The attitude of the German Philosopher to science is not always one of indifference. It is often an attitude of open hostility.” The writings of Hans Reichenbach would, Hook thought, be of great interest to the American reader, but in Germany Reichenbach is “ignored by academic philosophers as are all of his

42. Verein Ernst Mach, *Wissenschaftliche Weltauffassung. Der Wiener Kreis* (Vienna, 1929), 63 pp., on 9.

43. O. Spann, *Kategorienlehre* (1924), as quoted by P. Frank, *Das Kausalgesetz und seine Grenzen*, *Schriften zur wissenschaftlichen Weltauffassung*, Band 6 (Vienna, 1932), pp. 54-55.

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kind. . . ."⁴⁴ Two decades later, sketching the history of the Vienna Circle, Victor Kraft described the great resonance the movement found in western Europe and America, adding ruefully, "It was only in Germany that the Vienna Circle's approach was not taken up at all."⁴⁵

With the Bauhaus the case is somewhat different, for the movement of which Walter Gropius was the leading representative was indeed to a degree characteristic of Weimar culture.⁴⁶ Thus in this case we must ask, rather, if the new architecture and the associated movement in design were the expression of an impulse inherently congenial to the methods of the exact sciences or the achievements of modern technology. When one looks at the manifestos of this movement, however, one cannot but be struck by their ambivalence. In the first place, the initial conception and artistic direction of the Bauhaus was largely within the William Morris tradition of a return to handcrafts as a *reaction against* modern technology. When Gropius, in good measure out of simple financial necessity, began to reorient the institution toward industrial design, he had to face tenacious internal resistance. "With absolute conviction I reject the slogan 'Art and Technology—A New Unity,'" Lyonel Feininger wrote in a private letter in August 1923, "this misinterpretation of art is, however, a symptom of our times. And the demand for linking it with technology is absurd from every point of view." An antagonism toward science cum technology was even more explicit in the manifesto which Oskar Schlemmer drafted for the publicity pamphlet of the first Bauhaus exhibition in the summer of 1923.

44. S. Hook, "A Personal Impression of Contemporary German Philosophy," *Journal of Philosophy*, 27 (1930), 141-160, on 147, 159. The same view is stated less vigorously by Kurt Grelling, "Philosophy of the Exact Sciences [in Germany]," in *Philosophy Today*, ed. E. L. Schaub (Chicago, 1928), pp. 393-415.

45. V. Kraft, *Der Wiener Kreis. Der Ursprung des Neopositivismus. Ein Kapitel der jüngsten Philosophiegeschichte*, 2nd ed. (Vienna, 1968), p. 8. The first edition was published in 1950.

46. On the architectural side, this is well shown by Barbara Miller Lane, *Architecture and Politics in Germany, 1918-1945* (Cambridge, Mass., 1968). Cf. Gropius' speech before the Thuringian Landtag in Weimar on 9 July 1920: "Based on indisputable facts, I am now going to show convincingly that what the Bauhaus has accomplished is an uninterrupted and logical development that must take place, and already is taking place everywhere in the country." (Hans M. Wingler, ed., *The Bauhaus. Weimar, Dessau, Berlin, Chicago*, trans. W. Jabs and B. Gilbert [Cambridge, Mass., 1969], p. 42.)

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“Reason and science, ‘man’s greatest powers,’ are the regents, and the engineer is the sedate executor of unlimited possibilities. Mathematics, structure, and mechanization are the elements, and power and money are the dictators of these modern phenomena of steel, concrete, glass, and electricity . . . calculation seizes the transcendent world: art becomes a logarithm.”⁴⁷

Even Gropius himself, moreover, was thoroughly ambivalent on this question. “My primary aim” in planning the curriculum of the Bauhaus was “training the individual’s natural capacities to grasp life as a whole, a single cosmic entity. . . . Our guiding principle was that artistic design is neither an intellectual nor a material affair, but simply an integral part of the stuff of life.”⁴⁸ And so we return once again to *Lebensphilosophie*.

I.4. Educational Ideals and Reforms

Having gotten a clearer picture of the attitudes toward physical science and analytical rationality prevalent among the educated middle classes, and especially strong in the academic world in the Weimar period, we can now better appreciate the great apprehension with which the mathematicians and physicists viewed the movement for educational reform which followed in the wake of the revolution. And it is worthwhile to examine briefly the educational ideals announced by those in the Prussian Ministry of Education with the power to enact and administer such reforms, for one sees thereby both the resonance which these attitudes found across the political spectrum as well as the imminence of the threat to the physical sciences which these attitudes constituted.

The antirationalist theme was sounded at the opening of the Weimar period by Staatssekretär Carl Heinrich Becker. A distinguished Islamicist, Becker had entered the Prussian Education Ministry during the war and, qua Democrat, was elevated to the top civil service position after the Social Democrats threw out the *Kultus-*

47. Wingler, pp. 65-66, 69. The pamphlet was suppressed by the Bauhaus after it had been printed—not because of anything Schlemmer said about science, rationality, or technology, but because he had allowed a favorite Bauhaus slogan, “building the Cathedral of Socialism,” to slip into the manifesto.

48. W. Gropius, *The New Architecture and the Bauhaus*, trans. by P. M. Shand (London, 1935), pp. 52, 89.

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minister Friedrich Schmidt in November 1918.⁴⁹ "The basic evil," Becker asserted in 1919 in a widely read essay on university reform, "is the overvaluing of the purely intellectual in our cultural activity, the exclusive predominance of the rationalistic mode of thought, which had to lead, and has led, to egoism and materialism of the crassest form." And again, in another pamphlet written at this same time, Becker maintained that "our entire educational system is too exclusively oriented toward the intellect. We must acquire again reverence for the irrational."⁵⁰ This is all perhaps not too surprising in an academic *Geisteswissenschaftler*. It must give one pause, however, when one finds Becker's superior, the Social Democratic *Kultusminister* Konrad Haenisch propagating the same slogans (recall the rationalist-materialist traditions of his party!): "But if . . . the German people, having suffered for decades from the plight of mechanism and materialism, . . . if in our spiritual life not only the intellectual but also the irrational is to receive its due, then the barriers will have to be broken down which presently separate the universities and the people. . . ."⁵¹

One thus sees that whatever considerations may have led government officials to support and advance academic research in the physical sciences, the attitude of these "progressive" politicians and

49. Erich Wende, *C. H. Becker, Mensch und Politiker* (Stuttgart, 1959). Cf. Friedrich Schmidt-Ott, *Erlebtes und Erstrebtes, 1860-1950* (Wiesbaden, 1952).

50. C. H. Becker, *Gedanken zur Hochschulreform* (Leipzig, 1919), p. ix; *Kulturpolitische Aufgaben des Reiches* (Leipzig, 1919), p. 55: "Wir müssen wieder Ehrfurcht bekommen vor dem Irrationalen." For further examples see Adolf Grimme, ed., *Kulturverwaltung der zwanziger Jahre: Alte Dokumente und neue Beiträge* (Stuttgart, 1961), pp. 78-79; Wende, *op. cit.* (note 49), p. 305. Cf. the remarks of William D. McElroy, Director of the U.S. National Science Foundation, at Indiana University, 12 October 1970: "In my view, the science community generally should consider more carefully . . . 'the new romanticism,' emphasizing man as an emotional and feeling creature as well as a reasoning one. A healthy dose of this view may counterbalance some of the extreme emphasis upon rational thinking I suspect is endemic within the science community." (*Science*, 170 [1970], 517.)

51. K. Haenisch, *Staat und Hochschule* (Berlin, 1920), pp. 110-111, as quoted by Ringer, *op. cit.* (note 28), p. 282. Haenisch's general readiness to adopt the political and social ideologies of the German academics has been stressed by Hans Peter Bleuel, *Deutschlands Bekenner; Professoren zwischen Kaiserreich und Diktatur* (Berne, 1968), pp. 128-129. Ten years later the Social Democrats once again claimed the Prussian *Kultusministerium*. Their man, Adolph Grimme, was soon writing to Martin Heidegger, 14 May 1930, "as admirer and in a modest sense as pupil. . . . I don't have to tell you how very anxious I am [to get Heidegger to Berlin]. With you here a particular type of philosophy, above all metaphysics, could break through in Berlin." (Grimme, *Briefe*, ed. D. Sauberzweig [Heidelberg, 1967], pp. 36-37.)

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bureaucrats toward the “hard” sciences, and particularly toward the intellectual style they associated with these disciplines, was certainly not unambiguously affirmative.⁵² “The mood of decisive circles,” Wilhelm Hillers warned the Mathematischer Reichsverband in 1921, “is unfavorable to the natural sciences.” And when the Prussian education ministry’s plan for the reform of the secondary school curricula finally appeared in the spring of 1924, it proved even worse than had been feared. Taking it for granted that “the economic-political, technical, and positivistic age . . . now lies behind us,” the ministry refused to justify any part of the curricula on utilitarian grounds. The claims of mathematics and natural science derived from, and only from, the fact that “not only in Kant but also in Goethe [these types of thinking] have co-determined to the very depths the vital features of German idealism”—which, however, was insufficient merit to save these subjects from substantial reductions in the amount of time allotted them. To the older generation of mathematicians and physicists—to Friedrich Poske, Georg Hamel, Felix Klein—who had been struggling since the nineties to make a generous place for their disciplines in the German secondary schools, it seemed that all had been in vain: “This school reform,” Klein remarked bitterly, “signifies for our educational system the end of the century of science.”⁵³

52. A principal consideration underlying the relatively high level of financial support for academic research in the physical sciences was, once again, prestige—in particular the image of science as a *substitute* for political and economic power. See: Brigitte Schröder-Gudehus, *Deutsche Wissenschaft und internationale Zusammenarbeit* (diss. Geneva, 1966), pp. 181-189, 199; P. Forman, “Scientific Internationalism and the Weimar Physicists,” *Science, War, and Internationalism, 1900-1939*, ed. Roger Hahn (in press).

53. W. Hillers, *Jahresbericht der Deutschen Mathematiker-Vereinigung*, 31 (1922), Part 2, pp. 120-121. *Die Neuordnung des preussischen höheren Schulwesens: Denkschrift des Preussischen Ministeriums für Wissenschaft, Kunst und Volksbildung* (Berlin, 1924), reprinted in Hans Richert, ed., *Richtlinien für die Lehrpläne der höheren Schulen Preussens*, 7th ed. (Berlin, 1927), 1, 17-77, on 68-70. F. Klein quoted indirectly by F. Poske, “Der naturwissenschaftliche Unterricht und die Neuordnung des preussischen höheren Schulwesens,” *Naturwiss.*, 13 (1925), 73-75. Klein himself, in a letter to G. Hamel, remarked on the “remarkable circumstance that the development of the German school system has taken an entirely different direction” than the one he had foreseen in his address of June 1918. (*Unterrichtsblätter für Mathematik und Naturwissenschaft*, 30 [1924], 44-45). Hamel, speaking for the Mathematischer Reichsverband (*Jahresbericht der Deutschen Mathematiker-Vereinigung*, 33 [1924], Part 2, p. 63), quite agreed: “In fact the new school reform signifies the complete repudiation of [Abkehr von] the previous development . . . throws us way back before the time of the first school reform of 1892.”

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I.5. The Crisis of *Wissenschaft*

In the preceding sections I have explored from several directions the attitudes toward science and reason permeating the intellectual environment of the Weimar physicists and mathematicians. But the intellectual milieu is not fully characterized by a specification of such *substantive* constituents, not even when the catalog of valuations is supplemented by a measure of the intensity with which each of these attitudes is held. To fully characterize an intellectual atmosphere one must specify not merely the likes and dislikes, the sympathies and antipathies, but also the mood, the morale, the accepted view of the contemporary cultural situation, and the common notions of what that situation demanded, or where it must lead.

Turning back once again to the general intellectual historians and to the contemporary observers of the intellectual scene, we find as before remarkable unanimity about this essential dimension of the intellectual milieu: widespread among the educated middle classes, but especially oppressive in academia, was a generalized sense of crisis. Included therein was the permanent political and economic crisis, but, far from being limited to this, the fundamental phenomenon was felt to be a moral and intellectual crisis, a crisis of culture, a crisis of science and scholarship. Fritz Ringer, who has given the closest attention to German academic ideology, and, in particular, to this "crisis of learning," found that:

Throughout the Weimar period, it was often said in academic circles that a crisis was in progress. No one felt the need to define the exact nature of this crisis, to ask where it came from or what it involved. "Sometimes [the educator Aloys Fischer wrote in 1924], the present situation is represented as a crisis of the . . . economic system only, sometimes as one of politics and of the idea of the state, or as a crisis of the social order. At other times it is conceived more deeply and inclusively as a crisis of the entire intellectual and spiritual culture. . . ." In any case, the crisis existed, if only by virtue of the fact that almost every educated German believed in its reality.⁵⁴

54. Ringer, *op. cit.* (note 28), p. 245. It would be more accurate, perhaps, to say that although many academics did indeed feel a need to define the exact nature of this crisis, the diagnoses were often diametrically opposed. For example, Arthur Liebert, *Die geistige Krisis der Gegenwart*, 2nd ed. (Berlin, 1923),

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This notion of a crisis in or of learning, although it had roots running back into the previous century, emerged as a universally cogent cliché only in the aftermath of Germany's defeat. "The phrase 'Krisis der Wissenschaft' has already become a popular slogan in everyone's mouth," the political economist Arthur Salz noted in 1921.⁵⁵ So it continued throughout the Weimar period: "The idea of such a crisis of culture [Kulturkrise]," Pierre Viénot observed a decade later, "belongs today to the solid stock of the common habit of thought in Germany. It is a part of the German mentality."⁵⁶ And at a quarter century's distance it remained clear to Werner Richter, Becker's lieutenant in charge of the University Section of

pp. 7-9, expressed this need very forcefully: the purpose of his essay "is not to establish and portray any one arbitrarily selected crisis from contemporary life, no matter how staggering a force it may possess. The intent is much rather to expose *the* crisis of our time and of simply the entire contemporary world view and life mood, i.e. the concept and meaning of all the individual crises and the common spiritual and metaphysical wellspring by which they are all conditioned and from which they are all fed." This *he* found in "the disastrous historical scepticism and relativism nourished by historicism."

55. A. Salz, *Für die Wissenschaft. Gegen die Gebildeten unter ihren Verächtern* (Munich, 1921), p. 10. Typical for this period, and perhaps for this sort of phenomenon, is the circumstance that even the "opponents" shared in large measure the attitudes they were attacking. Thus Troeltsch, *op. cit.* (note 32), p. 1026, found Salz's essay "very instructive and symptomatic, above all in its almost fatalistic surrender to the anti-scientific, and in that sense revolutionary, currents." Another, more pertinent, example of this circumstance is Adolf von Harnack, historian-theologian but President of the Kaiser-Wilhelm-Gesellschaft. Responding to Karl Barth's challenge, hurling his "Fünfzehn Fragen an die Verächter der wissenschaftlichen Theologie unter den Theologen [1923]," Harnack warned against efforts "to revile, indeed eliminate reason [Vernunft]. . . . Does not gnostic occultism even now raise itself upon the ruins?" Yet on another occasion ("Stufen wissenschaftlicher Erkenntnis [1930]") we find this spokesman for the interests of the natural sciences declaring that "our intellect [Verstand] is the born mathematical physicist; like the mathematical physicist it abstracts, it calculates, it weighs." But "this abstracting method which corresponds to mechanism" is incapable of grasping the "life," "forms," "wholes" which surround us. Moreover natural science is only the second step in the cognitive hierarchy; above it stands knowledge of life, followed by knowledge of man, while the fifth, last, and highest step is occupied by philosophy. (Harnack, *Ausgewählte Reden und Aufsätze*, ed. A. von Zahn-Harnack and Axel von Harnack [Berlin, 1951], pp. 132-134, 177-180.)

56. P. Viénot, *Ungewisses Deutschland. Zur Krise seiner bürgerlichen Kultur*, trans. Eva Mertens (Frankfurt a.M., 1931), pp. 24-25. Typical is the observation of the former Prussian Minister of Education Otto Boelitz, in *Grundsätzliches zur Kulturlage der Gegenwart*, Flugschriften der deutschen Volkspartei, Folge 77 (Berlin, 1931), p. 5: "so gehe ich aus von der Kennzeichnung der Kultur der Gegenwart als einer Kulturkrisis."

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the Prussian Ministry of Education, that "The self-image [Selbstverständnis] of that period was decisively influenced by the consciousness of a crisis of culture."⁵⁷ I will return in Part II to consider how this generalized sense of crisis may have affected the rhetoric and the *Selbstverständnis* of the Weimar physicists and mathematicians; here I would only emphasize that implicit in this sense of crisis was a negative valuation of the traditional scientific disciplines, methods, and practitioners. If the educated public were convinced that "today's *Wissenschaft*, together with its methods, has run up a blind alley,"⁵⁸ then, inevitably, the stature of those who had cultivated these sciences by these methods would be considerably diminished. Conversely, if the scholar or scientist was to maintain his prestige in his academic environment and beyond, he too would have to acknowledge and affirm the crisis, would have to repudiate the traditional methods and doctrines of his discipline.⁵⁹

It was, of course, especially the radical *Lebensphilosophen* who pressed this interpretation of the crisis of learning. As a crisis of "causal monism," of positivistic methods in *Wissenschaft*, the crisis of learning must be followed by a revolution which liquidates this barren and intolerable mechanism in favor of a "new *Wissenschaft*" of values, intuition, feeling, of the living, the organic.⁶⁰ But the

57. W. Richter, *Wissenschaft und Geist in der Weimarer Republik*, Arbeitsgemeinschaft für Forschung des Landes Nordrhein-Westfalen, Geisteswissenschaften, Nr. 80 (Cologne, 1958), 31 pp., on 11.

58. A. Salz, *op. cit.* (note 55), p. 10. Cf. Hermann Weyl, "Felix Kleins Stellung in der mathematischen Gegenwart," *Naturwiss.*, 18 (1930), 4-11, on 6: "der Typus des Gelehrten und die Wissenschaft in ihrer Geltung und ihrem Wert während der letzten Jahrzehnte in Frage gestellt waren, im Zeichen der Krisis standen." (Reprinted in Weyl's *Gesammelte Abhandlungen* [Berlin, 1968], 3, 292-299.)

59. The Weimar academics were indeed much agitated by a variety of perceived threats to their social prestige, their intellectual leadership, and their economic situation. Yet, by and large, they saw democracy and republican institutions as the cause of their falling esteem, and rather looked to *Lebensphilosophie* to restore their power and prestige. Cf. note 40, above.

60. E. Troeltsch, *op. cit.* (note 32), p. 1023. To take but one of innumerable examples: Ernst Barthel, Privatdozent U. Köln, in an essay on "Mechanischer und organischer Naturbegriff," *Annalen der Philosophie*, 5 (1925), 57-76, argued that the "three principles" of space, time, and causality have been sufficiently analyzed and recognized as the "fundaments of rational thought. . . . It is, however, also generally conceded that the usual rational thinking through of the world totality assuming these principles leads to essential antinomies and incomprehensibilities, which bring thought to the limits of its competence. The organic conception of nature would like to ask itself now, whether it could

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conviction of the reality of this crisis of learning—including the image of science in a cul de sac—was even more widely spread than formal *Lebensphilosophie* itself. Thus “the collapse of science” was also trumpeted vigorously by Hugo Dingler, a prolific and widely read philosopher of physics, whose orientation was strongly rationalistic: “The state where nothing is any longer really certain, everything is possible and at the same time every possible position is also maintained, where there is no longer any basis and any guidelines, nothing, nothing which may be considered certain—in a word, chaos, collapse. In that state we stand; right in the middle of it. The public does not suspect it, and the *Gelehrten*, often frantically, shut their eyes.”⁶¹ And in Dingler’s view “this new collapse of science, in whose midst we stand . . . consists in the collapse of the belief in the certainty of the experimental principle,” i.e., of the possibility of establishing the truth of a theory upon its agreement with experiment.⁶²

Here the “crisis of learning” begins to touch the Weimar physicists very nearly. And when we find the aging and conservative professor of Experimental Physics at Privatdozent Dingler’s institution taking advantage of his term as rector to contradict and deplore the notion of “the collapse of science,” at least in respect of his own science,⁶³ then I think it fair to infer that the physicists who could not or would not join the revolution saw such doctrines as diminishing their claims and threatening their prestige both in the academic world and among the public at large.

possibly be that the one and only way of thinking is to make three abstract principles the basis for explanation of a world full of concrete living contents, or whether, on the contrary, also the opposite way . . .” (p. 71). The exploration of this “opposite way” leads to the conclusion of the article (pp. 75-76) that “the quality of the phenomena and their mutual connection lies in a region of noncausal [nichtkausal] harmony, which is to be grasped only by the intuition” and that, in general, one may distinguish between “mechanical” and “organic” scientific research in that the aim of the former is “practically utilizable, hypothetical causal abstractions, of the latter an intuitive cognition of the immanent essential connections.”

61. H. Dingler, *Der Zusammenbruch der Wissenschaft und der Primat der Philosophie*, 2nd ed. (Munich, 1931), p. 10. The second edition differs from the first, 1926, only in the addition of supplementary notes.

62. *Loc. cit.*

63. W. Wien, *Vergangenheit, Gegenwart und Zukunft der Physik. Rede, gehalten beim Stiftungsfest der Universität München am 19. Juni 1926*, Münchener Universitätsreden, Heft 7 (Munich, 1926), 18 pp., on 18.

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I.6. Spengler's *Decline of the West*

The crisis of culture, the revolution in *Wissenschaft*, radical *Lebensphilosophie*, all proclaimed and epitomized by a sweeping theory of world history in which—"das ist das Neue"⁶⁴—physics and mathematics are treated alongside art, music, and religion as wholly culturally conditioned. The first volume of Oswald Spengler's *Der Untergang des Abendlandes*,⁶⁵ in which the theory is presented and to which the extensive discussions of science are largely confined, appeared in 1918. Although at certain points it bore the stamp of the wartime mind—as, for example, in its positive valuation of technology—on the whole its fatalistic-relativistic pessimism was precisely the right tone for a defeated Germany. In five years the first volume went through thirty printings, and by 1926 the revised edition published in 1923 had gone through a further thirty printings—altogether 100,000 copies in a country with scarcely three times that number of college graduates. Almost universally read in academic circles—by the physicists, too, as we shall see—the typical professorial reaction was: "Of my discipline Spengler understands, of course, not the first thing, but aside from that the book is brilliant."⁶⁶

Ernst Troeltsch saw the first volume of the *Untergang* as the paradigm of the revolution in science: "It is the first decisive public

64. E. Troeltsch's review of the first volume of *Der Untergang* in the *Historische Zeitschrift* (1919), reprinted in Troeltsch's *Ges. Schr.*, 4 (*op. cit.*, note 32), 682. Troeltsch found it, inter alia, "ein bedeutsames Kulturdokument aus der Zeit einer geistigen Krisis der deutschen Wissenschaft."

65. O. Spengler, *Der Untergang des Abendlandes. Umriss einer Morphologie der Weltgeschichte*. Vol. 1: *Gestalt und Wirklichkeit* (Munich, 1918). The first thirty-two editions are unaltered, and of these the third through thirty-second (1920-1922) have essentially the same pagination; I refer to these latter editions as the "orig. ed." Editions 33 through 47, published in 1923, are the revised edition; they all have the same pagination and are referred to as the "rev. ed." The English translation of the revised edition by C. F. Atkinson, *The Decline of the West*, Vol. 1: *Form and Actuality* (New York: Knopf, 1926) is referred to as the "Eng. ed."

66. Or so it appeared to Gerhard Hessenberg, *Vom Sinn der Zahlen. Akademische Antrittsrede, gehalten an der Universität Tübingen am 8. Dezember 1921* (Leipzig, 1922), 56 pp., on 31. So also had it appeared to Hessenberg's friend Leonard Nelson, *Spuk; Einweihung in das Geheimnis der Wahrsagerkunst Oswald Spenglers . . .* (Leipzig, 1921). And in 1923 Friedrich Meinecke noted (*op. cit.*, note 36) that "When the first volume of the *Decline of the West* appeared one frequently heard from the circle of professional scholars [Fachgelehrten] the judgment: 'What he says about my field is, indeed, complete nonsense. But all the rest is very ingenious [geistreich].'"

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revelation of the new *Wissenschaft*, and thereupon rests a great part of its captivating effect.” For Lukács, Spengler is the characteristic representative of the *Lebensphilosophie* of the postwar years.⁶⁷ And for us his book is all the more valuable as an index of the attitudes toward science and reason in the intellectual environment of the early Weimar period because, on the one hand, it gives a prominent place to physics and mathematics, and because, on the other hand, it was the one expression of those attitudes to which the Weimar physicists and mathematicians uniformly exposed themselves.

The Spenglerian account of world history is based on the proposition that the principal cultures are autonomous organisms, each wholly unique apart from a common life cycle. Every cultural manifestation—art, science, or whatever—is simply and solely an expression of the soul of that particular culture and as such is neither “valid” nor even comprehensible outside that culture, i.e., at any other time or place: “Each culture has its own new possibilities of self-expression which arise, ripen, decay, and never return. There is not *one* sculpture, *one* painting, *one* mathematics, *one* physics, but many, each in its deepest essence different from the other, each limited in duration and self-contained.”⁶⁸

After sketching his program in the “Introduction,” Spengler aims in his first chapter, “The Meaning of Numbers,” to establish this thesis of mutual nonintelligibility once and for all by proving (by iteration) that “There is not and cannot be number as such. There are several number-worlds because there are several cultures.”⁶⁹ Likewise, “There is no mathematic, but only mathematics.”⁷⁰ In the following chapters this radical relativism is extended to natural science, above all, to physics.

And in fact, in the historian’s view there is only a *history of physics*. All its systems now appear to him as neither correct nor incorrect, but

67. Troeltsch, *op. cit.* (note 32), p. 1014. Lukács, *Zerstörung der Vernunft* (*op. cit.*, note 25), pp. 364–378. The same general view of Spengler’s role is taken by Helmut Kuhn, “Das geistige Gesicht der Weimarer Zeit,” *Zeitschr. f. Politik*, 8 (1961), 1–10.

68. Orig. ed., p. 29; rev. ed., p. 29; Eng. ed., p. 21.

69. Orig. ed., p. 85; rev. ed., p. 81; Eng. ed., p. 59.

70. “Es gibt keine Mathematik, es gibt nur Mathematiken.” (Orig. ed., p. 88; rev. ed., p. 83; Eng. ed., p. 60.)

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as historically, psychologically conditioned by the character of the epoch, and representing that character more or less completely.⁷¹

. . . a first-rate scientist of the time of Archimedes would have declared himself, after a thorough study of our modern theoretical physics, quite unable to comprehend how anyone could assert such arbitrary, grotesque, and involved notions to be science, still less how they could be claimed as necessary consequences from actual facts.⁷²

Writing off all criteria for the truth of a scientific theory as themselves culture-bound illusions, and dismissing with a wave of his hand the argument from the fact that “the machine works,” as Boltzmann put it, Spengler maintained: “There simply are no conceptions other than anthropomorphic conceptions . . . so is it certainly with every physical theory, no matter how well founded it is supposed to be. Every such is itself a myth, and in all its features anthropomorphically preformed. There is no pure natural science, there is not even a natural science which could be designated as common to all men [als allgemein menschlich].”⁷³ And although Spengler was a bit less categorical in the second edition, altogether his extension of extreme cultural relativism to physics and mathematics was meant and was received as a direct challenge to the ideology of the exact scientists. At first they might refuse to hear anything of it, but, asked repeatedly for their reactions, within a year or two they all had to confront it.

Still more important for our present inquiry than Spengler’s notorious theses regarding the nonobjectivity of the exact sciences are Spengler’s specific interpretations of post-Renaissance physics, its content and its future. The content of Western physics and mathematics is, of course, but an expression of the soul of Western culture—of the “Faustian” culture, as Spengler calls it. And the essential, determinative characteristic of “Faustian” science is, we are no longer surprised to learn, “the *Kausalitätsprinzip*—the logical form of the Faustian world-feeling:”⁷⁴ “We see then that the causality-principle, in the form in which it is selfevidently necessary for us—the agreed basis of truth for our mathematics, physics and philos-

71. Orig. ed., p. 167; deleted in rev. ed.

72. Orig. ed., p. 530; rev. ed., p. 491; Eng. ed., p. 380.

73. Orig. ed., p. 533; deleted in rev. ed.

74. Orig. ed., p. 551; deleted in rev. ed.

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ophy—is a Western and, more strictly speaking, Baroque phenomenon. . . .”⁷⁵ But although causality has reigned supreme in modern exact science, it is nonetheless—here comes the *Lebensphilosophie*—an artificial construction erected as a defense against the more fundamental, and fundamentally irrational, notion of destiny, *Schicksal*. This, indeed, is the “key” to the problem of world history:

I mean the opposition of the *destiny-idea* and the *causality-principle*, an opposition which, in its deep world-shaping necessity, has never hitherto been recognized as such. . . . Destiny is the word for an indescribable inner certainty. One makes the essence of the causal clear by means of a physical or epistemological system, by means of numbers, by means of conceptual analyses. . . . The one requires us to dismember, the other to create, and therein lies the relation of destiny to life and causality to death.⁷⁶

Thus we have the fundamental *lebensphilosophisch* theme, with which we are already all too familiar, inflated to cosmic proportions. Over and over again Spengler equates causality, conceptual analysis, and physics, and flays them across the stage of world history.

For the principle of causality is late, unusual, and only for the energetic intellect of higher cultures a secure, somewhat artificial possession. Out of it speaks fear of the world. Into it the intellect banishes the demonical in the form of a continually valid necessity, which rigid [starr] and soul-destroying is spread over the physical world-picture. Causality is coextensive with the concept of law. There are only causal-laws.⁷⁷

The abstract savant, the natural scientist, the thinker in systems, whose entire mental existence is founded upon the principle of causality, is a “late” manifestation of the hatred of the powers of destiny, of the incomprehensible.⁷⁸

The words “time” and “destiny,” for anyone who uses them instinctively, touch life itself in its deepest depths—life as a whole, which is not to be separated from lived experience. On the other hand, physics,

75. Orig. ed., p. 549; rev. ed., pp. 507-508; Eng. ed., p. 392.

76. Orig. ed., pp. 164-165; slightly, but insignificantly, altered in the rev. ed., pp. 154-155; Eng. ed., pp. 117-118.

77. Orig. ed., p. 165; first sentence modified and second and third sentences omitted in rev. ed., p. 155; Eng. ed., p. 118.

78. Orig. ed., pp. 168-169; rev. ed., p. 158; Eng. ed., p. 120.

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reason, *must* separate them. The livingly-experienced in itself, detached from the living act of the observer and become an object, dead, inorganic, rigid [starr]—that is now Nature as mechanism, i.e., as something to be exhausted mathematically. . . . This is the eternal embarrassment of all physics as the expression of a soul. All physics is treatment of the problem of motion, in which lies the problem of life itself, not as if it could one day be solved, but even though it is unsolvable.⁷⁹

Striking in this last passage is Spengler's elaboration of a notional complex advanced by Bergson and soon to be codified as existentialism in such works as Heidegger's *Being and Time*.⁸⁰ Time, Spengler assures us, is "something intensely personal," indeed, "we ourselves, insofar as we live, are time." It follows, therefore, that physics really "has nothing whatever to do with time," knows no direction of time, eliminates time in favor of a "web of cause and effect . . . of timeless duration."⁸¹ Likewise to be noted for later reference is Spengler's favorite epithet for causality—*starr*, i.e., stiff, rigid; it is intended to evoke and reinforce an antithesis between causality and life, an association of causality with death (cf. *die Totenstarre*, rigor mortis).⁸²

Spengler's indictment of physics=causality is all the weightier because he pretends to be a connoisseur of the physical sciences and modern technology, for whom "the depths and refinement of mathematical and physical theories are a joy," who "would sooner have the splendidly clear, highly intellectual forms of a fast steamer, of a steel structure, of a precision lathe, the subtlety and elegance of certain chemical and optical processes, than all the pickings and stealings of present day applied art, architecture and painting included."⁸³ *He* is not to be dismissed as an aesthete, a romantic; *he* is a hard-headed realist who, with a full appreciation of modern physics, "our ripest and strictest science,"⁸⁴ "the masterpiece of the Faustian spirit,"⁸⁵

79. Orig. ed., pp. 542-543; rev. ed., pp. 501-502, where the sentence "This is the eternal embarrassment . . ." is deleted; Eng. ed., pp. 388-389. Cf. Harnack (*op. cit.*, note 55): "our intellect is the born mathematical physicist."

80. Published in Edmund Husserl's *Jahrbuch für Philosophie und phänomenologische Forschung*, 8 (1927), 1-438.

81. Orig. ed., pp. 170-172; rev. ed., pp. 158-160; Eng. ed., pp. 120-122.

82. Thus orig. ed., pp. 69, 165, 167, 574, and p. 156 of the rev. ed. where an additional *starr* is added: "die starre Weltmaske der Kausalität."

83. Orig. ed., p. 60; rev. ed., p. 60; Eng. ed., pp. 43-44.

84. Orig. ed., p. 215; rev. ed., p. 205; Eng. ed., p. 156.

85. Orig. ed., p. 608; deleted in rev. ed.

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tells us what sort of cultural manifestation it really is, and what, according to the ineluctable cycle of cultural development, its fate must be.

Before us there stands a last spiritual crisis that will involve all Europe and America. What its course will be late Hellenism tells us. The tyranny of reason—of which we are not conscious, for the present generation is its apex—is in every culture an epoch between man and old-man, and no more. Its most distinct expression is the cult of the exact sciences, of dialectics, of demonstration, of causality.⁸⁶

Now, the history of the higher cultures shows that “science” is a transitory spectacle, belonging only to the autumn and winter of their life-courses, and that . . . a few centuries suffice for the complete exhaustion of its possibilities. Classical science faded out between the battle of Cannae [216 B.C.] and that of Actium [31 B.C.] and made way for the world outlook of the “second religiousness.” And from this it is possible to calculate in advance the end of western natural science.⁸⁷

It remains now to sketch the last stage of western science. From our standpoint of today the already declining route is clearly visible. . . . In this very century, I prophesy, in the age of scientific-critical Alexandrianism, resignation will overcome the will to victory of science. European science is advancing toward self-destruction through refinement of the intellect. . . . But from skepsis a path leads to the “second religiousness.” . . . No one yet believes in the exhaustion of the spirit even though we already feel it acutely in all our limbs. But two hundred years of civilization and orgies of scientificness—then one is fed up. Not the individual, but the soul of the culture itself has had enough, and expresses this by choosing to put into the historical field of the day ever smaller, narrower, and more unfruitful researchers . . . in physics as in chemistry, in biology as in mathematics, the great masters are dead, and we are experiencing today the decrescendo of the stragglers, who arrange, collect, and conclude, like the Alexandrians of the Roman period.⁸⁸

86. Orig. ed., pp. 607-608; rev. ed., p. 551; Eng. ed., p. 424.

87. Orig. ed., p. 532; rev. ed., p. 492, where the phrase “and made way for the world-outlook of the ‘second religiousness’” was added and the final sentence softened to: “And from this it is possible to foresee a date at which our Western scientific thought shall have reached the limit of its evolution.” (Eng. ed., p. 381.)

88. Orig. ed., pp. 607-609; rev. ed., pp. 551-553, where altered slightly but insignificantly; Eng. ed., pp. 424-425.

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I would happily let this stand—and it was meant to stand—as the measure of Spengler’s world-historical vision, for a more erroneous description and valuation of early twentieth-century physics could scarcely be devised. Yet as perverse and denigrating as this image is, it must still be recognized for what it was—an integral part of an analysis of Western culture, its present state, and its future prospects, which expressed and shaped the notions and inclinations of the educated middle classes in postwar Germany.

In another respect, however, Spengler’s analysis of contemporary physics, confused and contradictory like all else in his treatise, shows a flash of prescience. For physics in his generation is not merely plodding forward in a beaten track, tying up loose ends, it is also, according to Spengler, disintegrating *and* metamorphizing, undergoing a transformation of the goals and principles of scientific explanation paralleling the *Zeitgeist*, the “second religiousness.”

Western European physics—let no one deceive himself—has reached the limit of its possibilities. . . . This is the origin of the sudden and annihilating doubt that has arisen about things that even yesterday were the unchallenged foundation of physical theory, about the meaning of the energy principle, the concepts of mass, space, absolute time, and causal natural laws generally [n.b.] . . . this doubt extends to the very possibility of a natural science. What deep and utterly unconscious skepsis lies, for example, in the rapidly increasing use of enumerative and statistical methods, which aim only at the probability of the results, and forgo in advance the absolute exactitude of the laws of nature, as one understood it in hopeful earlier generations.⁸⁹

It is not, of course, to the quantum theory which Spengler refers here in the original edition. In speaking of the concepts of mass, space, time, energy he evidently has above all the theory of relativity in mind, and it is primarily to the atomistic foundation of the second law of thermodynamics that the remarks about statistics and probability refer. But the talk of doubt about the concept of causal natural laws points beyond these theories; I do not myself know just what Spengler, the seer, has in mind,⁹⁰ but his images and associa-

89. Orig. ed., pp. 596-597; rev. ed., pp. 541-542, where again modified insignificantly; Eng. ed., pp. 417-418.

90. Uncited, like virtually all of Spengler’s sources, but almost certainly important was Wilhelm Wien’s “Ziele und Methoden der theoretischen Physik.

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tions are certainly suggestive of those which, as I show in Part III, soon after begin to appear in the writings of German theoretical physicists.

Statistics belong, like chronology, to the domain of the organic, to fluctuating life, to destiny and incident and not to the world of exact laws and timeless eternal mechanics. . . .

The more dynamics exhausts its inner possibilities as it nears the goal . . . the more insistently the organic necessity of destiny asserts itself side by side with the inorganic necessity of causality. . . . The course of this process is marked by the appearance of a whole series of daring hypotheses, all of like sort. . . . Above all, this is manifested in the bizarre hypotheses of atomic disintegration. . . . This destiny strikes only a few individuals in an aggregate of radioactive atoms, the neighbors being entirely unaffected.⁹¹

Here, then, is the fate and the salvation of physics—a reunification of thought and feeling, a self-discovery of physics as a fundamentally religious-anthropomorphic expression:

The goal reached, the vast and ever more meaningless and threadbare fabric woven by natural science falls apart. It was, after all, nothing but the inner structure of the mind. . . . But what appears under the fabric is once again the earliest and deepest, the myth, immediate becoming, life itself. . . . Out of the religious soulfulness of the gothic there grew up the urban intellect, the alter ego of irreligious natural science, overshadowing the original world feeling. But today, in the sunset of the scientific epoch, in the stage of victorious skepsis, the clouds dissolve and the quiet landscape of the morning reappears in all distinctness. . . . weary after its striving, the Western science returns to its spiritual home.⁹²

Festrede . . . Universität zu Würzburg. Gehalten am 11. Mai 1914," printed in several places at that time and reprinted in Wien, *Aus der Welt der Wissenschaft. Vorträge und Aufsätze* (Leipzig, 1921), pp. 150-171. If this is the case, the doubts about causality which Spengler thinks he finds among the physicists, like so much of what Spengler reads into and out of his scientific sources, is simply a confusion. If, however, Spengler is drawing upon Max Planck's *Festrede* of 4 August 1914 (see note 158 below) he has evidently understood his author very well.

91. Orig. ed., pp. 603, 605-606; rev. ed., pp. 547 (where "timeless eternal mechanics" becomes "timeless causality"), 549-550; Eng. ed., pp. 421, 423.

92. Orig. ed., pp. 614-615; rev. ed., pp. 556-557; Eng. ed., pp. 427-428.

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II. ADAPTATION OF IDEOLOGY TO THE INTELLECTUAL ENVIRONMENT

II.1. Introduction

Spengler epitomizes for us a set of attitudes, widely diffused among educated Germans, explicitly hostile to the ideology of the exact sciences and to particular concepts employed within them. In the remainder of this paper I explore some aspects of the response of the representatives of these sciences in German-speaking Central Europe—in the first instance of the response at the level of ideology; i.e., I explore the effect of this intellectual environment upon the professed justifications of scientific activity, upon the epistemological stance of the exact scientists, and upon their elan, their esprit, their confidence in the future of their discipline.

I do not, however, undertake to construct here a comprehensive typology of ideological responses to the Weimar intellectual milieu, but limit myself to illustrating a few of the more striking ideological adaptations. The resulting picture, emphasizing examples of accommodation, but not examples of resistance, is necessarily one-sided. Nonetheless, the imbalance is not as great as one might expect, both because the instances of a physicist or mathematician forcefully advancing ideals antithetic to those of his milieu are rare indeed, especially before the last years of the Weimar period,^{93,94} and

93. Apart from the literature discussed below (Part III) in connection with the dispute over the law of causality, examples from the early Weimar period are almost exclusively in the form of, and limited to, rejections and rebuttals of Spengler's book and theses. Such are the tracts by Leonard Nelson and Gerhard Hessenberg cited in note 66; P. Riebesell, "Die Mathematik und die Naturwissenschaften in Spengler's 'Untergang des Abendlandes,'" *Naturwiss.*, 8 (1920), 507-509; and the preface to the second edition of Franz Exner's *Vorlesungen über die physikalischen Grundlagen der Naturwissenschaften* (Leipzig-Vienna, 1922), pp. vi-xiii. Other affirmations of the "scientific approach" are at the very least ambivalent: so, for example, the "Introduction" to Max Born's *Die Relativitätstheorie Einsteins* (1920), trans. H. L. Brose as *Einstein's Theory of Relativity* (London, 1924), pp. 1-6. In reprinting the "Einleitung" as the first selection in Born's *Physik im Wandel meiner Zeit*, 4th enlarged ed. (Braunschweig, 1966) the highly characteristic epigraph from Goethe was omitted: "The most perfect pleasure of the thinking human being is to have successfully researched that which is researchable, and to calmly revere that which is unresearchable."

94. Only two outspoken, unambivalent affirmations of an antithetic ideal before an academic audience are known to me; both are from the late Weimar period when, as Sontheimer has pointed out (*op. cit.*, note 26, pp. 43 ff.), there

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because, as we shall see, it is often the case that the same scientist who in one context offers resistance to the antiscientific currents of his milieu, in another context can be found flirting with propositions intimately associated with those same currents. Moreover, this one side of the scientist's response is particularly interesting and instructive as largely contradicting the usual assumption of the intellectual autonomy of modern professionalized scientific disciplines. It thus provides essential motivation and support for my contention in Part III that the German physicists' predisposition toward acausal laws of nature likewise arose as a form of accommodation to their intellectual environment.

was a general stiffening of resistance among intellectuals to irrationalism: Richard von Mises, *Über das naturwissenschaftliche Weltbild der Gegenwart. Rede bei der Feier . . . der Berliner Universität . . . am 27. Juli 1930* (Berlin, 1930), 29 pp., reprinted in *Naturwiss.*, 18 (1930), 885-899; Konrad Knopp, "Der Einfluss der Naturwissenschaft auf das moderne Bildungsideal," in H. Gerber, ed., *Die Universität. Ihre Geschichte, Aufgabe und Bedeutung in der Gegenwart. Öffentliche Vorträge der Universität Tübingen, Wintersemester 1932-33* (Stuttgart, 1933), pp. 189-217. Mention might here also be made of Wilhelm Blaschke, *Leonardo und die Naturwissenschaften. Rede, gehalten am 10. November 1927, zum Antritt des Rektorats an der Universität Hamburg*, *Hamburger mathematische Einzelschriften* 4 (Leipzig, 1928), 15 pp.; of Walther Kossel's *Die Einheit der Naturwissenschaft. Rede beim Antritt des Rektorats der . . . Universität [Kiel] am 5. März 1929* (Kiel, 1929), 22 pp.; and certainly also of the closing lines of David Hilbert's public address at the Naturforscherversammlung in Königsberg in September 1930, "Naturerkennen und Logik," *Naturwiss.*, 18 (1930), 959-963, reprinted in Hilbert's *Gesammelte Abhandlungen*, 3 (Berlin, 1935; reprinted New York, 1965), 378-387: "he who is sensible of the truth of the liberal way of thinking and world view which shines forth from these words of Jacobi, he does not succumb to reactionary and unfruitful scepticism; he will not believe those who today with philosophic mien and superior tone prophesy the decline of western culture [den Kulturuntergang] and take pleasure in declaring 'ignorabimus.' For the mathematician there is no 'ignorabimus,' and equally for natural science, in my opinion, there is none whatsoever. . . . The true reason that Comte was not able to find an insoluble problem is, in my opinion, that there simply does not exist an insoluble problem. In place of this foolish 'ignorabimus' let our solution on the contrary be: We must know./ We will know." Hermann Weyl, "Zu David Hilberts siebzigstem Geburtstag," *Naturwiss.*, 20 (22 January 1932), 57-58, reprinted in Weyl's *Ges. Abhl.*, 3, 346-347, quoted this last sentence, adding that "our contemporaries are not glad to hear that sort of thing; they see in it shallow-minded rationalism or human presumption and with a torrent of confused words appeal to 'life itself' or the deeper 'existential truth' or the 'creatureliness' of man as justifying their repudiation of reason [Ratio]. And granted; a sentence here and there in Hilbert's address sounds suspiciously like the words with which Gottfried Keller ridiculed his natural scientist. . . . Nonetheless, one does Hilbert an injustice if one tosses his rationalism into the same pot with, say, that of a Haeckel."

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As today with the “ecology” fad, so also in the Weimar period it was the biologist who could most easily adapt his ideology and values to those of his intellectual milieu. Life, that central symbol, was his own subject. Paraphrasing a spokesman for the discipline,⁹⁵ of all natural sciences biology merits an especially ample place in the school curriculum for it is least deserving of the reproach of aiming at “knowledge for power”; its mission is to counter the alienation from nature in our technical age; it provides the link between the *Naturwissenschaften* and the *Geisteswissenschaften* because it works in part with the concept of scientific law, but also with the techniques of understanding and imparting of meaning; it brings us to the edge of the irrational and teaches us to respect that which is beyond rational investigation. Nor are these arguments merely for public and governmental consumption; the eminent embryologist Hans Spemann, recommending to his eldest son a recent work on the philosophy of education, praises the author, Eduard Spranger, because he “above all treats the living and the spiritual with reverence and the love of the artist; he lets it live and doesn’t pluck it apart into dead little pieces.”⁹⁶ But although the materials are richer in some respects, and the evidence of the influence of the intellectual milieu more flagrant, biology is not my subject.

II.2. From Positivism to *Lebensphilosophie*

From his term as rector of the University of Würzburg in 1914 until his death in 1928 Wilhelm Wien was—alongside Max Planck—the most prominent spokesman for physics in Germany. His semi-popular essays and addresses fall especially densely in the period 1918–1926, and so offer us a most striking example of the very quick change of tune which followed Germany’s defeat in the First World War. On 1 May 1918, speaking in Dorpat on “Physics and the

95. Philipp Depdolla, “Biologie,” *Unterrichtsblätter für Mathematik und Naturwissenschaft*, 37 (1931), 183-190.

96. Letter of 12 October 1928 quoted in H. Spemann, *Forschung und Leben*, ed. Friedrich Wilhelm Spemann (Stuttgart, 1943), p. 229. One cannot but feel some sympathy for Spemann who had to bear through the early twentieth century the cross of “*Entwicklungsmechanik*” which the late nineteenth century had fastened upon his field.

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Theory of Knowledge,” Wien emphasized the independence and autonomy of physics—from philosophy, especially; for aid, physics calls only upon mathematics, chemistry, and technology. Helmholtz, he stated flatly and unapologetically, was a “pure empiricist in particular opposition to the German idealist philosophy, above all to Hegel.” More important, the bulk of the lecture was given over to a discussion of Ernst Mach’s views, which Wien accepted in large measure with some conventionalist and some realist modifications.⁹⁷ In his Machianism and, more to the point, in his readiness to advocate it before a general academic audience, Wien was at this moment by no means unusual. That same summer, in his address as rector of the University of Göttingen, Hermann Th. Simon, applied physicist, delivered himself of a thoroughly positivist account of how we obtain knowledge of the world through adaptation of our ideas to our sensations, basing himself upon Mach and Avenarius.⁹⁸

Compare, now, Willy Wien as he appears in September 1919 in an article commemorating the twenty-fifth anniversary of Helmholtz’ death.⁹⁹ In an apologetic tone Wien explained that while it is true that Helmholtz became an empiricist “through opposition to the Hegelian school”—n.b., not to idealism—and that he was never able to give up this position, nonetheless Helmholtz was always concerned with the “totality of the sciences,” and always had “ideal,” not “material,” goals in view, always aimed at the “dominion of the spirit.” Wien thus implicitly concedes the series of equations made repeatedly by the antagonists of modern science—empiricism = positivism = narrow specialization = utilitarianism = materialism—attempting only to make an exception of Helmholtz, who, we are assured, were he alive today would look to “German idealism” to put us on our feet again. In this essay there is, of course, not the faintest whiff of positivism; no mention of Mach at all. By February 1920, Wien’s own “idealism” had matured so far that in addressing

97. W. Wien, “Physik und Erkenntnistheorie. Vortrag, gehalten in Dorpat am 1. Mai 1918,” *Aus der Welt der Wissenschaft. Vorträge und Aufsätze* (Leipzig, 1921), pp. 209-234.

98. H. Th. Simon, *Leben und Wissenschaft, Wissenschaft und Leben. Rektoratsrede zur Jahresfeier der Georgia Augusta [Universität Göttingen] am 26. Juni 1918* (Leipzig, 1918), 32 pp.

99. W. Wien, “Hermann von Helmholtz,” reprinted from *Naturwiss.*, 7 (5 September 1919), 645-648, in *Aus der Welt der Wissenschaft*, pp. 86-94.

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a public session of the Prussian Academy of Sciences on "The Connections Between Physics and Other Disciplines" he represented the "postulate of the cognizability of nature" as "in the final analysis not so very far from the fundamental idea of the Hegelian philosophy of identity,"¹⁰⁰ and in November 1925 he could be found shedding tears before his assembled university over the abandonment, some twenty years earlier, of the requirement that philosophy, the "unifying discipline," be one of the subordinate subjects in every Ph.D. examination at a German university.¹⁰¹

Wien may well be the only German physicist to have expressed regret for that requirement, but he is certainly far from unusual in announcing a recent reversal of an earlier, deplorable trend toward fragmentation and isolation of physics from other disciplines,¹⁰² or in thoroughly suppressing his earlier positivism. I know of only one instance during the entire Weimar period of a German physicist venturing, in a general academic address, to mention Mach's name with clear approbation and to associate himself with Mach's epistemological doctrines. Nor was it mere coincidence that in taking this courageous stand at the *end* of the Weimar period Richard von Mises refused to associate himself with the demand for synthesis, "counting it"—as did Mach—"the highest philosophy to tolerate an incomplete world view."¹⁰³

The renunciation of positivism was intimately connected—for

100. W. Wien, "Über die Beziehungen der Physik zu andern Wissenschaften. Öffentlicher Vortrag, gehalten in der Preussischen Akademie der Wissenschaften in Berlin am 27. Februar 1920," *Aus der Welt der Wiss.*, pp. 16-40, on 28. And again, eighteen months later, we can find Walther Nernst pursuing the question in his *Rektorats-Antrittsrede* "ob nicht, wie fast stets bei derartigen starken geistigen Strömungen, auch in der Identitätsphilosophie ein gesunder Kern steckt." (*Naturwiss.*, 10 [1922], 489-495, on 490.)

101. W. Wien, *Universalität und Einzelforschung. Rektorats-Antrittsrede, gehalten am 28. November 1925*, Münchener Universitätsreden, Heft 5 (Munich, 1926), 19 pp., on 14-15. All the German universities except Berlin had abandoned this requirement at the beginning of the century.

102. The rebutting of the charge of fragmentation, of disintegration of the world picture by specialized research, is surely the single most common theme of general academic lectures by physicists. So Hermann Weyl, *op. cit.* (note 58): "To be sure one hears over and over complaints about the extent of specialization in the sciences. I believe, however, that on the whole in recent decades the situation has gotten better rather than worse." Likewise, Walther Kossel, *Die Einheit der Naturwissenschaft* (*op. cit.*, note 94).

103. R. von Mises, *Über das naturwissenschaftliche Weltbild* (*op. cit.*, note 94), p. 27. W. Ostwald, *Lebenslinien* (*op. cit.*, note 19), 2, 312.

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Wien as for all his fellow physicists—with a renunciation of “knowledge for power,” of the harnessing of nature, of utility as the object, motive, or justification for scientific research. In June 1914, reviewing as rector of the University of Würzburg the development of the German universities in the preceding century, Wien had given only one measure of achievement for the fields of physics and chemistry, viz. that they “have created the solid foundations upon which the pillars of our industry are erected,” and he had reproached the universities for failing to incorporate the *Technische Hochschulen* as technical faculties.¹⁰⁴ In May 1918 Wien’s lecture on “Physics and Epistemology,” rejecting any liaison with philosophy, was followed a few days later by one on “Physics and Technology,” whose basic, endlessly exemplified theme was the “support and stimulation” which *these* two fields have received from one another and should continue to receive in the future.¹⁰⁵ In the following years Wien did indeed play a key role in the creation and operation of the Helmholtz-Gesellschaft, which for the first time channeled substantial financial support from German industry into the physical institutes of the German universities. Yet in his academic addresses of the Weimar period he never let slip even a single word about this compromising connection.¹⁰⁶

The shift in that element of the ideology defining “the significance of physical research” was announced by Wien in his address before the Prussian Academy of Sciences in February 1920. This question, we are told, can be judged from two very different points of view. The first sees physical research as aiming at “human domination over the recalcitrant forces of nature.” Wien implicitly recognizes

104. W. Wien, “Die neuere Entwicklung unserer Universitäten und ihre Stellung im deutschen Geistesleben. Rede für den Festakt in der neuen Universität am 29. Juni 1914,” *Aus der Welt der Wissenschaft*, pp. 1-15, on 14.

105. W. Wien, “Physik und Technik, Vortrag, gehalten in Reval am 6. Mai 1918,” *Aus der Welt der Wiss.*, pp. 235-263.

106. W. Wien, “Die Helmholtz-Gesellschaft und ihre Bedeutung für die deutsche Physik . . .,” *Die Helmholtz-Gesellschaft zur Förderung der physikalisch-technischen Forschung in sieben Jahren ihres Wirkens* [privately printed], 1928), pp. 7-11. This renunciation of utility in academia was not wholly uncompensated. The slogan “knowledge for power” was exchanged for “knowledge as a substitute for power,” “Wissenschaft als Macht-Ersatz.” See B. Schröder, *op. cit.* (note 52). It must be said, moreover, that the academic chemists, unlike the physicists, do not appear to have become at all bashful about discussing technical applications and justifying their science through them.

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that his audience is very hostile to any such conception, and after pointing out that it need not necessarily proceed from a "purely materialistic mode of thought," passes on to the second and proper point of view, one "free of all striving toward a goal [Zielstrebigen]." Physical research is, in truth, nothing but the expression of "the pure human instinct for inquiry"; "it arises solely from an inner need of the human spirit"—note the implicit *Lebensphilosophie*—"a craving," Wien explains, "to grasp the causality of events."¹⁰⁷ To this new line Wien held fast in all further academic addresses. In November 1925, as rector of the University of Munich, his discussion of "Universality and Specialized Research" touches on technological applications of physical science in only one paragraph, and there only in order to stress that scientific ideas which appear at first to refer to but a narrow field may turn out to have enormous practical consequences. He is very careful, however, not to appear to be praising science on that account. Throughout the lecture Wien totally abstains from any attempt to justify science by utility. On the contrary, the goal of science is *culture*: "The significance of a scientific achievement can ultimately only be measured by the effect which it has upon the intellectual life"; "the results of research are worthless if they are not taken up into the culture."¹⁰⁸

As Wien's reference to causality suggests, he had very strong views on which results of research ought to be taken up into the culture and which ought not. And although, as will appear in Part III, many of Wien's colleagues took a different view of the concept of causality, they were in complete agreement with him on the motive, goal, and justification for physical research. The "common driving force" of

107. W. Wien, *op. cit.* (note 100), p. 28. Cf. the mineralogist Gottlob Linck, *Über Wesen und Wert der Universität. Rede, gehalten . . . am 19. Juni 1920 . . . zu Jena vom Rektor der Universität* (Jena, 1920), p. 4: "Wie der Hirsch schreiet nach frischem Wasser, so schreiet unsere Seele nach Erkenntnis."

108. W. Wien, *op. cit.* (note 101), pp. 13, 7, and 19, respectively. Cf. the theoretical physicist Erwin Madelung, *Die Bedeutung der Wissenschaft im Rahmen unserer Kultur. Rede anlässlich der Übernahme des Rektorates* [1931], Frankfurter Universitätsreden 39 (Frankfurt a. M., 1932), 16 pp., who explains (pp. 2-4) that by "Kultur" he understands "everything which broadens and enriches our inner life, which is, I believe, in sufficient accord with the customary usage. . . . We want, thus, to put completely aside here the consideration of practical utilizability and of the dead piling up of information, however important it may be. We want only to ask ourselves what spiritual needs [geistige Bedürfnisse] we have and to what extent these are satisfied by science." Naturally, "our needs arise out of the dark spring of our living existence."

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all the research in the university—as the members of the University of Greifswald learned from their new rector, the *applied physicist* Friedrich Krüger—is “the innate human urge for ever new knowledge. . . . All external driving forces originating in considerations of utility and necessity for our physical existence and its advancement are completely without influence.” And, after this introduction, Krüger devoted his *Rektoratsrede* to the question of the heat death of the universe!¹⁰⁹

This ideology tinged with *Lebensphilosophie*—that the value of physics lies in and derives from the fact that it is the expression of an unanalyzable and irreducible human drive (for cognition of nature, in this case)—attained by 1929 the status of orthodox physical doctrine, occupying the opening pages of the volume on “General Foundations of Physics” in the new edition of the *Handbuch der Physik*. Firmly rejecting technological application as a measure of the value of physical knowledge, and, less firmly, rejecting the foundation of a *Weltanschauung* as the goal of physical research, Hans Reichenbach explained that “the most important thing that one can say about it [i.e., doing physics] is that it is a need, that it grows up out of the human being just like the wish to live, or to play, or to form a community with others.”¹¹⁰

At first sight it seems most surprising that even a Reichenbach, i.e., even a representative of “rigorous” logical empiricism, should have taken over the standards of value and the ideology for the physical enterprise from an intellectual milieu specifically hostile to his philosophical position. This circumstance becomes less surprising

109. F. Krüger, *Materie und Energie im Welt-Geschehen. Rektoratsrede*, Greifswalder Universitätsreden 15 (Greifswald, 1928), 29 pp. “Alle äusseren Triebkräfte des Nützlichen und für die äussere Existenz und ihre Förderung Notwendigen kommen nicht in Frage” (p. 3). Only at the end of his address, apropos of artificial disintegration of atoms, did Krüger make any reference at all to the application of scientific knowledge, namely to “extracting the energy of the atom as one of the greatest technical problems worthy of the most strenuous efforts . . . consequently we see at present a mighty contest in the laboratories of the civilized nations . . . to find the methods for extracting this energy” (pp. 28-29).

110. H. Reichenbach, “Ziele und Wege der physikalischen Erkenntnis,” *Handbuch der Physik*, Band 4: *Allgemeine Grundlagen der Physik*, ed. H. Thirring (Berlin, 1929), pp. 1-80, on 1-2. As for the new discipline of “technical physics,” Reichenbach dismisses it (p. 11) with the remark that even though it has now attained a place in German universities “sie ist doch ihrem Wesen nach eine Technik und keine Wissenschaft,” for a *Wissenschaft* aims solely at “Erkenntnis.”

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if one recalls that the positivist tradition itself contained a substantial element of *Lebensphilosophie* and that, moreover, there was a solid Machian precedent for regarding natural science as the outgrowth of a basic human drive. How horrified Hedwig Born would have been had she known that her favorite Einsteinian apothegm—"I feel such solidarity with everything living, that it is all one to me where the individual begins and ends," which she heard at his bedside as he lay critically ill in 1917/18 and which she found so beautiful that she quoted it over and over again to Einstein himself¹¹¹—was also in fact a most genuinely Machian-positivist sentiment.

Yet with such sentiments we have by no means reached the limits of the community of values and attitudes between the physical scientist and his *lebensphilosophisch* intellectual milieu. The "unbroken life force" of mathematics, the "concrete nearness to life" of applied mathematics, the "*lebensvollste* interlacing" of mathematics with natural science and technology, the training of students by "living interaction to spontaneous scientific work," the maintaining of mathematics "in contact with the concrete stuff of life," and avoiding the danger that it will "rigidify as a pure distant-from-life form"—these examples of "life" rhetoric are all drawn from a single address, a bare half dozen pages, by Richard Courant.¹¹² To be sure Courant's rhetoric of "life," "organism," "spontaneity," "ecstasy," "phantasy," "instinct," "intuition" is considerably more exuberant than that of most of his colleagues. It is indicative, nonetheless, of a substantial participation by the physicist and mathematician in the values of his general cultural milieu.

Another striking example of this participation is the assent of the exact scientists to the proposition that feeling and intellect are antithetic, incapable of coexisting in an exalted state in a single individual, and that feeling is the higher quality.¹¹³ Einstein

111. Born-Einstein, *Briefwechsel* (*op. cit.*, note 14), p. 113.

112. R. Courant, "Über die allgemeine Bedeutung des mathematischen Denkens," *Naturwiss.*, 16 (1928), 89-94. "Vortrag, Tagung Deutscher Philologen und Schulmänner, Göttingen, September 1927." Under the cover of this rhetoric, however, Courant basically stands firm upon the traditional intellectualist conception and cognitive claims of mathematics.

113. The "classical" exponent of this thesis was Ludwig Klages, who is still counted a great seer in Germany today. Indeed the press of the Deutsche Physikalische Gesellschaft recently published a collection of essays—*Physik, Gleichung*

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expressed this very well in a letter to H. A. Lorentz: “In your case Nature had the rare impulse to unite with a sharp mind warm feeling. If only this were often so. . . .”¹¹⁴ Given this ranking, it is not surprising that the physicists and mathematicians responded so ineffectually to the charge of “intellectualism” leveled by Becker *et al.* Nor is it surprising that they themselves sought the motive, goal, and justification for their own scientific activity in feeling and instinct, in the wish for, not in the fact of, cognition. As Wilhelm Ostwald, now in his old age, so succinctly put it, “the reason, and science along with it, is only a servant of the feeling.”¹¹⁵

Here, moreover, we must add that most curious simile in Reichenbach’s explanation of why one does physics—it is “like the wish to form a community with others,” the characteristic emotional need of the Weimar period. In the famous “Introduction” to his book on *Einstein’s Theory of Relativity*, written in 1920, Max Born gave expression to this same longing for “community,” for participation in some whole which transcends the individual, maintaining that “all religions, philosophies, sciences are procedures designed for the purpose of expanding the ‘I’ to the ‘we’.” What distinguishes the natural scientist is his resolve—“often shuddering”—to achieve this goal by sacrificing the absolute for the sake of objectivity. And it is in *this* way that, for the physicist, “the pain of spiritual loneliness disappears, the bridge to kindred spirits is formed.”¹¹⁶ And with

und Gleichnis. Vorträge und Aufsätze über Physik (Mosbach i. B., 1967)—by Eberhard Buchwald, a mediocre theorist who in the 1920’s was struggling to make a career in applied physics. There one can read, pp. 68-80, Buchwald’s contribution to *Ludwig Klages, Erforscher und Kündler des Lebens* (Linz, 1947), and learn what Klages, “enthroned” alongside Heraclitus, Goethe, and Nietzsche, can mean to a “dankerfüllten Fachphysiker.”

114. Einstein to H. A. Lorentz, 3 April 1917. Microfilm of Lorentz papers in the Algemeen Rijksarchief, The Hague, deposited in the Archive for History of Quantum Physics (see note 13); on microfilm nr. 6. For the higher status of feeling: Einstein to Hedwig Born, 1 Sept. 1919, *Briefwechsel* (*op. cit.*, note 14), pp. 32-33, and Einstein to Jacob Laub [1909?], as quoted by Carl Seelig, *Albert Einstein: Eine dokumentarische Biographie* (Zurich, 1954), p. 117.

115. W. Ostwald, “Von der Formel zur Form,” *B.Z. am Mittag*, 3 Nov. 1926, as quoted in Grete Ostwald, *Wilhelm Ostwald, mein Vater* (Stuttgart, 1953), pp. 229-230.

116. M. Born, “Introduction” to *Einstein’s Theory of Relativity* (*op. cit.*, note 93). Born’s inclination toward what one might call “futurist *Lebensphilosophie*”—such as one finds expressed by Walther Rathenau, for example—is revealed in his recommendation of Richard N. Coudenhove-Kalergi’s *Apologie*

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this concession that science is primarily a means for satisfying certain emotional needs, we have arrived again at the very axiom of the “revolution in science.”

II.3. Capitulation to Spenglerism

A remarkable readiness of the Weimar physicists to adapt their ideology to the values of their milieu has, I think, been shown in the preceding section. Yet the adaptations displayed there, while they involve redefinitions of the motivation and justification for doing physics, do not explicitly alter the fundamental conceptions of scientific method, renounce the cognitive claims of the exact sciences, or resign confidence in their future development—as demanded and predicted by Spengler. But if we shift our focus slightly, from the physicists to the theoretical physicists and mathematicians, there appears a distinct tendency to carry the ideological adaptation into these vital regions and to adopt specific propositions which at the time were attributed to, or especially closely associated with, the *Untergang des Abendlandes*.¹¹⁷

A most interesting and most suggestive case of a clearly discernible Spenglerian influence is to be found in Richard von Mises' inaugural

der Technik (Leipzig, 1922), “dessen Inhalt mir sehr eingeleuchtet hat.” (Born to Einstein, 7 April 1923, *Briefwechsel* [*op. cit.*, note 14], p. 110.) On science as primarily a means to satisfy emotional needs, compare E. Madelung (*op. cit.*, note 108), p. 14, replying to those who place a higher value upon the *Geisteswissenschaften* than upon the *Naturwissenschaften*: “As for the value judgement, I want to emphasize once again that it obviously doesn't matter so very much what one does and what methods one employs, but far more how one views one's own activity, whether one feels richer and freer through it, and more secure vis-à-vis life's changing forms.”

117. The shift in focus away from the experimental physicists is in good part simply a consequence of their relative inarticulateness. But not entirely. If in general they did not go so far in their ideological accommodation as the theoretical physicists and mathematicians, that was also in part because they had less to recant. In the Weimar period the theoretical physicists seem to have drawn closer to the mathematicians with whom they were lumped for opprobrium in the public's mind, and with whom their relations could in some respects be less constrained than those which they maintained with the experimental physicists. Some twenty notable theoretical physicists held membership in the Deutsche Mathematiker-Vereinigung in 1924, half of whom had joined in or after 1918 (*Jahresbericht*, 34 [1925], Part 2, pp. 49-92), and that despite the fact that the annual meetings of the Deutsche Physikalische Gesellschaft and the Deutsche Mathematiker-Vereinigung were ordinarily held at the same time and place, thus largely obviating the need for formal membership in both organizations.

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(and farewell) lecture as Professor of Mechanics at the *Technische Hochschule* Dresden—delivered in February 1920, after von Mises had accepted a chair of applied mathematics at the University of Berlin. Considerable stir was created by von Mises' contention—or rather concession to the intellectual milieu—that the “age of technology,” to which the *Technische Hochschulen* owed their rise, was on its way out. His advice to these institutions was that they do their best to get onto the wave of the future by entering the field which was destined to replace technology in the “culture consciousness,” namely speculative natural science, particularly relativity and atomic physics. In these subjects, he asserted, we have had for the past two decades a period like that of Copernicus, Galileo, and Kepler. “It is not a question of new facts of any sort, nor of new theoretical propositions, nor even of new methods of research, but, if I may say it—taking this word in its philosophical sense—of new intuitions [Anschauungen] of the world.” Atomic physics has taken up again “the question of the old alchemists”; “numerical harmonies, even numerical mysteries play a role, reminding one no less of the ideas of the pythagoreans than of some of the cabbalists.”¹¹⁸

Astonishing as these remarks are from the mouth of a convinced positivist, impossible as it may be to find their like two years earlier, much as they remind us of Spengler's prediction that a new mysticism was the fate and salvation of natural science, still *prima facie* evidence of a connection with the *Decline of the West* is wanting. In fact, the immediate precedent and probable inspiration for von Mises' reference to numerical harmonies and mysteries is an article on “A Number Mystery in the Theory of the Zeeman Effect” by Arnold Sommerfeld which appeared in *Die Naturwissenschaften* a few weeks earlier, as well as the preface to Sommerfeld's *Atomic Structure and Spectral Lines*, which had appeared late in 1919.¹¹⁹

118. R. v. Mises, *Naturwissenschaft und Technik der Gegenwart. Eine akademische Rede mit Zusätzen, Abhandlungen und Vorträge aus dem Gebiete der Mathematik, Naturwissenschaft und Technik*, Heft 8 (Leipzig, 1922), 32 pp., on 2, 5, 16, respectively. The initial publication without the *Zusätze* had been in the *Zeitschr. des Vereins deutscher Ingenieure*, 64 (1920), 687-690, 717-719.

119. A. Sommerfeld, “Ein Zahlenmysterium in der Theorie des Zeeman-effektes,” *Naturwiss.*, 8 (23 Jan. 1920), 61-64, on which see my “Alfred Landé and the Anomalous Zeeman Effect, 1919-1921,” *Historical Studies in the Physical Sciences*, 2 (1970), 153-261; Sommerfeld, *Atombau und Spektrallinien*, 1st ed. (Braunschweig, 1919), p. viii. Sommerfeld was sufficiently pleased with this *Sphärenmusik* passage to reprint it in the 2nd, 3rd, and 4th editions, 1920-1924.

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There Sommerfeld had spoken of “the mysterious organ upon which nature plays the spectral music” of the atomic spheres. In the future Sommerfeld was to go considerably further in this direction. A ceremonial address at a public session of the Bavarian Academy of Sciences in July 1925 offered Sommerfeld the opportunity to stress that “hand in hand with this turn toward the arithmetical goes a certain inclination of modern physics toward pythagorean number mysticism. Precisely the most successful researchers in the field of theoretical spectral analysis—Balmer, Rydberg, Ritz—were pronounced number mystics. . . . If only Kepler could have experienced today’s quantum theory! He would have seen the most daring dreams of his youth realized. . . .”¹²⁰

It is true that, having indulged himself in such rhetoric at some length, Sommerfeld concluded with the hope that he will “not be suspected of speaking in favor of mysticism in the ordinary sense, as it comes out in the astrological, metaphysical, and spiritualistic impulses of our time.” Nothing is farther from his intent, he insisted; he was not speaking of human things, but only of laws of nature, and he meant rather to be attacking “conventionalism,” “positivism,” and “Machian philosophy.”¹²¹ Yet it is perfectly clear that, despite the disclaimers, Sommerfeld was indeed catering to the antirational as well as the antipositivist inclinations of his audience, that he was trying to project an image of physics that would find favor with his audi-

120. A. Sommerfeld, *Die Bedeutung der Röntgenstrahlen für die heutige Physik. Festrede, gehalten in der öffentlichen Sitzung der B. Akademie der Wissenschaften . . . am 15. Juli 1925* (Munich, 1925), 17 pp., reprinted in Sommerfeld’s *Ges. Schr.* (*op. cit.*, note 21), 4, 564-579, on 573-574.

121. *Ibid.*, pp. 575-576. Cf. Georg Hamel, President of the Mathematischer Reichsverband, whom we have also previously seen throwing himself against the wave of irrationalism and anti-intellectualism, summarizing his *Rektoratsrede* delivered 30 June 1928 at the Technische Hochschule Berlin: “Mathematics customarily appears as the rational science per se; to the layman the mathematician is a calculator. In opposition thereto I maintain the thesis that mathematics is an art, and that, in the last analysis, it is conditioned not logically but transcendently. . . . The mathematician is a poet. Like the dramatist he creates a form. . . . The problem of the irrational numbers leads mathematics into metaphysics. . . . The genuine foundation for all of mathematics I see in Kant’s pure *Anschauung*. . . . In conclusion I take issue with the misconception that my remarks represent a repudiation of intellectualism. Although the irrational basis of mathematics has been clearly recognized, that does not alter in the least the mathematician’s obligation to proceed purely logically within his science, with the greatest care, with precise modes of inference.” (Hamel, “Ueber die philosophische Stellung der Mathematik,” *Forschungen und Fortschritte*, 4 [1928], 267.)

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tors and raise the prestige of the discipline in their eyes. And one cannot help but be struck at the close correspondence between this image and that which Spengler sketched in the final pages of the *Decline of the West*.

But let us return to von Mises—upon whom a direct influence of Spengler can in fact be established by September 1921. When at this time von Mises added an appendix to the republication of his lecture of February 1920, his tone had changed entirely, his optimism and enthusiasm had disappeared. Von Mises had largely, and *explicitly*, adopted Spengler's perspective and assumptions. It is "at least highly probable that the towering structure, under construction for the past five centuries, of a Western culture oriented entirely toward cognition and performance will collapse in the following centuries. From this standpoint one must count the theory of relativity and modern atomic physics as among the last building stones destined to crown the structure." Accepting Spengler's doctrine that cultures, as "living organisms," are fundamentally incommensurable, von Mises declared it "entirely out of the question" that the culture which succeeds ours will "continue the exact sciences in our sense." Nor can such views be dismissed as pessimism—"as if the man, who conscious of his old age and the inevitability of his death, is a pessimist because he faces the fact and acts accordingly."¹²² What, one wonders, would it mean for a physicist or mathematician to "act accordingly"? Could it possibly mean that he strives to alter the content of his science and the very nature of the scientific enterprise, in order to fulfill Spengler's prophecies?

What is perhaps most striking and appalling about the von Mises of September 1921 is the failure of nerve, the complete loss—just as Spengler predicted—of the esprit, the self-confidence which we expect from the mathematical physicist. And in this von Mises was by no means unique. One can find, on the contrary, many examples—most

122. R. v. Mises, *op. cit.* (note 118), p. 32. Cf. note 103 and text thereto. In general the shifts in von Mises' mental posture correspond quite closely to those which Georg Steinhausen, *Deutsche Geistes- und Kulturgeschichte von 1870 bis zur Gegenwart* (Halle a. d. Saale, 1931), p. 4, found to be typical for the Weimar period. Namely, initially, despite the political and military collapse, a certain euphoria over the wholly new epoch thus begun; this mood was, however, very soon displaced by disillusionment and an "Untergangsstimmung," which, again, had entirely disappeared by the late Weimar period when there was a strong tendency "to fall back into the old mental grooves."

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often in addresses before general academic audiences—of theoretical physicists and applied mathematicians denigrating the capacity of their discipline to attain true, or even valuable, knowledge. The earliest such is, perhaps, the passage which in the spring of 1918 Hermann Weyl placed as a conclusion to the first edition of *Space-Time-Matter*.¹²³ Theoretical physics is, Weyl maintained, entirely analogous to formal logic. “True” propositions must conform to logic, but logic is incapable of judging the “truth” of the propositions it manipulates; so also reality conforms to the laws of physics, but physics is incapable of informing us about the reality which its laws govern. Is, perhaps, this reality—these “darker depths” than the mathematician can grasp with his methods^{124,125}—Spengler’s “immediate becoming, life itself”? Indeed, as we shall see in Part III, it is.

A still more striking example of these same “annihilating doubts” is offered us by Gustav Doetsch in his inaugural lecture as Privatdozent for applied mathematics at the University of Halle, 27 January 1922. There, in conclusion, pointing back to his exposition of the “Meaning of Applied Mathematics,” Doetsch burst forth:

Such *rationalistic dogmatism* is the characteristic expression of that intellectual epoch which is at this moment perishing [im Untergehen]. It is the spirit, one could say, of the *age of natural science*, which, essentially, coincided with the 19th century, and which in our days is sinking with violent convulsions into its grave in order to make room

123. H. Weyl, *Raum-Zeit-Materie. Vorlesungen über allgemeine Relativitätstheorie*, 1st ed. (Berlin, 1918), pp. 226-227; again, somewhat more fully, in the 3rd ed. (Berlin, 1919), pp. 262-263. In the fall of 1920, when preparing the fourth edition (Berlin, 1921), Weyl struck this conclusion, replacing it by an attack on causality.

124. *Ibid.*, 1st ed., p. 9; 3rd ed., p. 9; 4th ed., p. 9.

125. Slightly later, and perhaps owing something to Weyl, is Paul Gruner, *Die Neuorientierung der Physik. Rektoratsrede, gehalten an . . . der Universität Bern den 26. November 1921* (Bern, 1922), 23 pp. In conclusion, theoretical physicist Gruner conceded that although “es mag dem Naturforscher schwer fallen,” his field cannot satisfy “das Sehnen nach absoluter Wahrheit” which fills contemporary academic youth. “Dem blossen Denken und Beobachten der Naturwissenschaften ist dieses intuitive Schauen versagt.” Natural science can tell us nothing of the meaning of the world and our life; the disaster we are experiencing today is due to this intellectual advance without ethical-religious foundation. These are, of course, precisely the charges which theoretical physicist von Laue, taking Rudolf Steiner as his ostensible target, was trying to rebut a few months later. (See note 15 and text thereto.)

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for a new spirit, a new life-feeling . . . this epoch, at whose beginning we unquestionably find ourselves today, is fed up with this rationalistic attitude. Whether we direct our attention toward expressionism in art, or to more recent philosophical tendencies, which in many ways have not yet emerged entirely distinctly, or to any other area of life and thought whatsoever, we find everywhere an ever stronger *aversion* for *that* spirit which believed that it had to express, and that it could express, everything whatsoever in dry words, in one formula—an aversion deriving from the unconscious feeling: *this* path has never and will never lead us to the *essence* of things, we must try to get “nearer” to the object, to transfer ourselves inside of it itself. Whether the new path leads to the goal, or whether it can only get us closer, may be left undecided. Here my intent was only to point out in the *domain of natural science itself*, which has served as a model for so many others, that the *mathematical* treatment of the material of experience does not begin to impart information about the essence of the world, that is, to yield true cognition.¹²⁶

And still Doetsch was not quite finished. After this tirade against his discipline he quoted Hegel’s dictum that mathematics is “kein Begreifen,” and clinched his case by observing that if Hegel “should not be regarded as the proper person to bring applied mathematics to a correct estimation of itself, then I refer to the words of our most brilliant contemporary mathematician, Hermann Weyl, in whose famous work, *Raum-Zeit-Materie*. . . .” It was, of course, rather daring of Doetsch to speak his mind *so* freely—although his general academic audience must have been very happy indeed to hear their views confirmed by a mathematician. It was, however, foolhardy of Privatdozent Doetsch to publish such sentiments in the journal of the German Society of Mathematicians, where it was read by, and had necessarily to offend, senior and influential colleagues. Indeed it may well have cost him a chair.¹²⁷

126. G. Doetsch, “Der Sinn der angewandten Mathematik,” *Jahresbericht der Deutschen Mathematiker-Vereinigung*, 31 (1922), 222–233, on 231–232. “Antrittsvorlesung gelegentlich der Umhabilitierung von der T. H. Hannover an die Universität Halle a/S. am 27. Januar 1922.”

127. *Ibid.*, p. 233. Otto Blumenthal to Theodor von Karman, 8 July 1923: “Das Ergebnis Ihrer Anfragen betreffs papabler Mathematiker finde ich im höchsten Masse betäubend. Ich habe von Doetsch nicht die Ansicht, dass er für uns brauchbar ist. C. Müller hat uns seiner Zeit ein sehr vernünftiges und abfälliges Gutachten über ihn gegeben. Auch habe ich von einem Vortrag, den er in Halle über das Wesen der angewandten Mathematik (D.M.V.) gehalten

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And finally, to place in evidence an example from the latter part of our period, consider the picture of "The Peculiar Nature of the Mathematician's Mind" which Max Dehn, Professor of Pure and Applied Mathematics, held up before his assembled university in January 1928. Painted in pure Spenglerian style, the characteristic mental tone of the contemporary [German] mathematician is skepsis, mistrust of reason, self-inculcation, pessimism, and resignation:

This somewhat sceptical attitude of many a contemporary mathematician is reinforced by what is going on in the neighboring field of physics. Here it appears to be the case that the physical phenomena no longer admit of being construed consistently [widerspruchslos] in a mathematical four-dimensional space-time manifold. Up to now we were able to provide physics with sufficiently freely built scaffolding for its ever bolder constructions. Now, however, in certain reflections arising from important investigations of the finest structure of matter, physics is perhaps in the process of cutting itself loose from mathematics. [Dehn is, *inter alia*, two years behind the times—see sections III.4–6.]

All this has impelled many of us to be somewhat sceptical in more general questions as well. The fundamental conviction of every philosopher that the world can be comprehended consistently [widerspruchslos] by the human reason is, for the mathematician, no longer certain. . . . This attitude is, to be sure, not entirely original; it is reminiscent of the thought of the later Eleatics at the time of the foundation crisis in ancient Greece.

Out of this skepsis there develops a certain resignation, a kind of mistrust for the power of the human mind in general.

. . . because of the boundedness of human intellectual power a limit is set to abstraction, to the departure from the intuition. Beyond this limit no further development is possible. But contemporary mathe-

hat, einen ungünstigen Eindruck erhalten, müsste mir allerdings den Artikel noch mal durchsehen" (Karman Papers, California Institute of Technology Archives, Box 13). By 1924 Doetsch had become reconciled to his discipline, and had even persuaded himself that although mathematics and natural science—"immediately casting everything into *rational* schemata"—"can never uncover the real meaning of the world and its interconnections, . . . nonetheless the mind [Geist] at least comes ever nearer to that which it would really like to grasp." ("Sinn der reinen Mathematik und ihrer Anwendungen," *Kant-Studien*, 29 (1924), 439-459, on 458-459; "Vorträge . . . Januar 1924.") And later that same year Doetsch received his first chair.

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matics is by no means dead, and naturally, even in topology, for example, a man can and hopefully will come who simplifies the processes so much . . . that a new development sets in. . . . Such achievements will, however, scarcely arise in the course of an organized routine. But if the mathematician is already complaining for this very reason—that in consequence of the modern development finally even the pursuit of his science has become organized—then he must properly say to himself: *mea maxima culpa*. For through mathematics the constructive power of the human being first unfolded, and thus brought forth the age of technology. And if, confronted by this disaster which he has brought about, the mathematician is seized with despair, then, for the third time, resignation saves him.¹²⁸

The foregoing examples—especially the cases of von Mises and Doetsch—demonstrate most clearly that there were mathematical physicists who went so far in assimilating the values and mood of their intellectual milieu as to effectively repudiate their own discipline. They show, moreover, that this process of ideological adaptation to the intellectual environment was, either explicitly or implicitly, in large measure a capitulation to Spenglerism. These cases are extreme, of course, and as such atypical. Yet the stages by which von Mises advanced to this extreme, and the readiness of even a Sommerfeld to flirt with the very antiscientific tendencies he deplored, makes it difficult to avoid the conclusion that most German mathematicians and physicists largely participated in, or accommodated their persona to, a generally Spenglerian point of view.

This conclusion is supported by the combination of ample evidence that Spengler's book was read by many, if not most, German physicists and mathematicians and the remarkable paucity of public criticism by representatives of these disciplines. In reviewing the

128. M. Dehn, *Über die geistige Eigenart des Mathematikers. Rede anlässlich der Gründungsfeier des Deutschen Reiches am 18. Januar 1928*, Frankfurter Universitätsreden 28 (Frankfurt, 1928), 20 pp., on 15, 18. This address by one of Hilbert's oldest students (Ph.D. Göttingen, 1899) seems to have drawn considerable attention. Otto Neugebauer quoted it, without citing it, in concluding his exposition of the elaborate installations of the new Göttingen mathematical institute (*op. cit.*, note 8). Although Neugebauer's final lines were in defense of "organisation," he did not fail to concede to Dehn that "Gewiss lässt sich auch für eine solche Auffassung viel ins Feld führen." One may therefore suppose that Hilbert's remarks in September 1930 (*op. cit.*, note 94) were meant as much for his colleagues—and former students—as for his lay audience.

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Untergang in 1919 Troeltsch had emphasized the desirability of such criticism, but reported that “to be sure, when I asked one of our most eminent mathematicians and physicists [Planck?] to give his opinion of the book, and briefly described Spengler’s principal theses, he refused to read any part of it.”¹²⁹ But that reaction was either untypical or changed very quickly, for I have seen explicit references to Spengler, either suggesting or demonstrating acquaintance with his book, by Max Born, Albert Einstein, Franz Exner, Philipp Frank, Gerhard Hessenberg, Pascual Jordan, Konrad Knopp, Richard von Mises, Friedrich Poske, Hermann Weyl, and Wilhelm Wien.¹³⁰ This list, which I expect could be substantially lengthened, is already of such extraordinary length as to make it virtually certain that Spengler’s theses, and not merely the public enthusiasm for them, were generally known to the Weimar physicists and mathematicians. And yet they did or said remarkably little to oppose them. Reviewing the literature of the “controversy over Spengler” in 1922 Manfred Schroeter found that “both the cornerposts of the book, the first and sixth chapters, mathematics and physics, have remained almost unanswered.” Indeed, Schroeter was able to find very few criticisms by mathematicians, and only one by a physicist—Wilhelm Wien.¹³¹

Where and when a physicist or mathematician came forward to attack Spengler it was almost invariably in defense of that most basic tenet of the scientific ideology, the autonomy, objectivity, and

129. E. Troeltsch, *Ges. Schr. (op. cit., note 32), 4*, 682.

130. Born-Einstein, *Briefwechsel (op. cit., note 14)*, p. 44; F. Exner, *op. cit.* (note 93), preface; P. Frank, *op. cit.* (note 43), p. 54; G. Hessenberg, *op. cit.* (note 66); P. Jordan, *Anschauliche Quantentheorie* (Berlin, 1936), p. 279; K. Knopp, *op. cit.* (note 94), p. 208, cf. note 131; R. v. Mises, *op. cit.* (note 117), p. 32; F. Poske, “Anschauliche und abstrakte Begriffsdefinitionen im physikalischen Unterricht. Vortrag, Naturforscherversammlung, Nauheim, September 1920,” *Zeitschr. f. den physikal. u. chemisch. Unterricht*, 34 (1921), 97-103 (“Den immerhin unvermeidlich intellektualistischen Charakter der theoretischen Physik hat neuerdings Oswald Spengler in seinem Buche, *Der Übergang [sic] des Abendlandes*, hervorgehoben,” and Poske reluctantly agreed, without an inkling of criticism); H. Weyl, “Das Raumproblem,” *Jahresber. d. Dtsch. Mathematiker-Vereinigung*, 31 (1922), 205-221, reprinted in Weyl’s *Gesammelte Abhandlungen*, ed. K. Chandrasekharan, 4 vols. (Berlin, 1968), 2, 332; W. Wien, *op. cit.* (note 100), pp. 36-39.

131. M. Schroeter, *Der Streit um Spengler. Kritik seiner Kritiker* (Munich, 1922), pp. 56-57, 70. The only scientist critics he knows are W. Wien, O. Neurath [sociologist], Leonard Nelson [philosopher], G. Hessenberg, and K. Knopp, who published a “sehr absprechend” review.

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universality of scientific knowledge.¹³² This notion Spengler claimed to have exploded by demonstrating that there are no immanent, invariant criteria of knowledge, that the science of a period is dependent in toto upon its *Lebensgefühl*. Yet for every opponent of Spengler's thesis one can cite another exact scientist who, more or less explicitly and more or less fully, identified himself with this doctrinal touchstone of Spenglerism.¹³³ And once again von Mises provides evidence

132. Thus the rebuttals cited in note 93.

133. Thus, for example, Gustav Mie, *Das Problem der Materie. Öffentliche Antrittsrede* [as Professor of Physics at the University of Freiburg i. Br.], *gehalten am 26. Januar 1925* (Freiburg in Baden, 1925), pp. 23-24: "Ich bin der Überzeugung, dass in der Geschichte der geistigen Bewegungen überall ein Zusammenhang der verschiedensten Gebiete des Geisteslebens zu beobachten ist. Der Atomismus ist ein Kind des 18. Jahrhunderts und des Rationalismus. . . . Deswegen sind wir im Begriff, uns einem andern Weltbild zuzuwenden. Ich glaube, dass dieses neue Weltbild gewisse charakteristische Züge trägt, die auch sonst im Bilde des modernen Geisteslebens auffallen, ich meine, das Suchen nach einer grossen Einheit und nach einem allgemeinen Zusammenhang im physikalischen Geschehen, der sehr gegen das Auseinanderfallen in die einzelnen Atome kontrastiert. Es ist eine interessante Beobachtung, dass auch die streng an experimentelle Erfahrungen gebundene Physik auf Bahnen geführt wird, die zu den Bahnen der geistigen Bewegungen auf anderen Gebieten durchaus parallel verlaufen."

Again R. Courant, Sept. 1927 (*op. cit.*, note 112), p. 90: "It is surely no accident that the *Umschwung* in the orientation of mathematics from naive productivity to rigorous scientificness is temporally parallel with the great intellectual and social transformations which the European world has undergone since the beginning of the French revolution."

Again E. Madelung, 1931 (*op. cit.*, note 108), pp. 4-6: "I can say without exaggerating that I have not the least interest in the world, but only in the picture [Bild] that I possess of it. Out of this picture I draw my joys and sufferings, my fear and hope, my feeling of comfort and of sorrow. . . . By means of language a communal world-picture is created as a convention. . . . We designate today as '*die Wissenschaft*' our stock of knowledge [Besitz an Wissen] which is codified by the written word and sanctified by convention."

And once again, E. Schrödinger, *Über Indeterminismus in der Physik. Ist die Naturwissenschaft milieubedingt? Zwei Vorträge zur Kritik der naturwissenschaftlichen Erkenntnis* (Leipzig, Barth, 1932), pp. 38-39: "Unsere Kultur bildet ein Ganzes. Auch wer das Glück hatte, die Forschung zu seinem Hauptberuf zu machen—ganz abgesehen davon, dass dies nicht die einzigen sind, die sie fördern,—ist doch nicht nur Botaniker, nur Physiker, nur Chemiker. Vormittags auf dem Katheder spricht er wohl der Hauptsache nach bloss von seinem Fach. An demselben Abend sitzt er in einer politischen Versammlung, hört und spricht ganz andere Dinge,—steht ein andermal im Kreis einer Weltanschauungsgemeinde, wo wieder von anderem die Rede ist. Man liest Romane und Gedichte, geht ins Theater, treibt Musik, macht Reisen, sieht Bilder, Skulpturen, Architektur—und vor allem, man liest und spricht viel über diese und andere Dinge. Kurz wir alle sind Mitglieder unseres Kulturmilieus. Sobald bei einer Sache die Einstellung unseres Interesses überhaupt eine Rolle spielt, muss das Milieu, der Kulturkreis, der Zeitgeist oder wie man es sonst nennen will, seinen Einfluss

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that the repudiation of this tenet of the scientific ideology was, in some cases and to some extent, a capitulation to the *Untergang, per se*. Thus in February 1920 von Mises had still been a good enough positivist to deny the influence of political and social conditions or the associated *Lebensgefühl* on the quantity, vitality, direction, or content of the higher intellectual productions. By September 1921, however, he had, as we have seen, gone over to Spengler in this respect as well.¹³⁴

II.4. A Craving for Crises

The exploration of the forms and extent of the ideological adaptation by the physical scientist to his environment must not stop at that unmarked and undefinable frontier where motivation and metaphysics end and the scientific activity itself begins. For to the ideology belongs not merely the general conceptions of the nature and goals of scientific activity, not merely the morale and esprit of the scientist, but also the scientist's perception of the state of his discipline, his hopes, fears, and expectations for its future development. Here, then, we return to the notion and mood of crisis, the conviction of a crisis of culture and of science, which was an essential component of the persona of the Weimar academics.

But before inquiring how far the German mathematical-physical community was likewise infected by this mood, how far a craving for crises affected the exact scientist's perception of the significance and bearing of specific scientific problems, it is worthwhile to emphasize how ready the mathematicians and physicists were to serve themselves with the crisis rhetoric when addressing a general academic audience. For as the notion of crisis became a cliché, it also became an entrée, a ploy to achieve instant "relevance," to establish rapport between the scientist and his auditors. By applying the word "crisis"

üben. Es werden sich auf allen Gebieten einer Kultur gemeinsame weltanschauliche Züge und, noch sehr viel zahlreicher, gemeinsame stilistische Züge vorfinden, in der Politik, in der Kunst, in der Wissenschaft. Wenn es gelingt, sie auch in der exakten Naturwissenschaft aufzuweisen, wird eine Art Indizienbeweis für Subjektivität and Milieubedingtheit erbracht sein." Translated very freely by James Murphy in Schrödinger, *Science, Theory, and Man* (New York, 1957), pp. 98-100.

134. R. v. Mises, *op. cit.* (note 117), pp. 3, 32.

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to his own discipline the scientist has not only made contact with his audience, but has *ipso facto* shown that his field—and he himself—is “with it,” sharing the spirit of the times. A presumption is thus insinuated, and often explicitly stated, that in the course of this crisis his science will shed all those characteristics which the academic audience finds most objectionable.^{135,136}

But now, unless we are willing to charge duplicity and suppose that the physicists and mathematicians were engaged in a cynical manipulation of their image, I think we must allow that their accommodation to the intellectual environment penetrated deeper

135. For example: Walter Schottky, “Das Kausalproblem der Quantentheorie als eine Grundfrage der modernen Naturforschung überhaupt. Versuch einer gemeinverständlichen Darstellung,” *Naturwiss.*, 9 (1921), 492-496, 506-511, opening paragraph: “Darstellung der Krisis in der sich die heutige Physik befindet”; M. H., “Ein Vortrag Einsteins: ‘Neue Ergebnisse über die Eigenschaften des Lichtes,’” *Neue Züricher Zeitung* (20 June 1922), nr. 808, p. 2: “The reason for the choice of precisely this theme was offered by the circumstance that in respect to the problem of the nature of light physics finds itself today in a severe crisis [sich heute . . . in einer schweren Krise befindet]”; Leo Graetz, *Alle Vorstellungen und neue Tatsachen der Physk. Drei Vorlesungen* (Leipzig, 1925), p. 1; Wilhelm Wien, “Kausalität und Statistik,” *Illustrierte Zeitung* (Leipzig), Nr. 4169 (February 1925), pp. 192-196: “Das Aufwerfen dieser Fragen hat die ganze theoretische Physik in eine Krisis gebracht”; Erhard Schmidt, *Über Gewissheit in der Mathematik. Rede zum Antritt des Rektorats der . . . Universität zu Berlin am 15. Oktober 1929* (Berlin, 1930), p. 12: “so steht in der Tat die mathematische Gewissheit in einer Krise”; Richard Gans, *Die Physik der letzten dreissig Jahre. Rede, gehalten bei der Reichsgründungsfeier am 18. Januar 1930*, Königsberger Universitätsreden 7 (Königsberg, 1930), p. 1: “. . . eine Krisis in der Physik heraufbeschworen hat, wie sie in unserer Wissenschaft vorher nicht bekannt war”; once again, Gans, “Der Zufall in der Physik,” *Schriften der Königsberger Gelehrten Gesellschaft, Naturwissenschaftliche Klasse*, 4 (1927), 113-125, opens: “I believe, however, that I may be permitted to claim your interest insofar as I want to try to show you what things excite the physicist today, and how he exerts himself to wind his way out of the most serious crisis in which our science has ever found itself”; Hans Hahn, ed., *Krise und Neuaufbau in den exakten Wissenschaften: Fünf Wiener Vorträge* (Leipzig-Vienna, 1933), Vorwort: “The growing interest of ever wider circles for the exact sciences is surely above all a seeking after one of the regions which are removed from the world of crises. . . . In truth the exact sciences are by no means secure from crises and precisely in recent decades, from theoretical physics on out into logic, they have been shaken by severe crises.”

136. One can find prewar precedents for this “crisis talk” in popular essays and academic addresses. So, for example, Paul Ehrenfest’s inaugural lecture as Professor of Theoretical Physics in Leiden, *Zur Krise der Lichtaether-Hypothese* (Leiden-Berlin, 1913), reprinted in Ehrenfest’s *Collected Scientific Papers*, ed. M. J. Klein (Amsterdam, 1959), pp. 306-327. Just how widespread this was, and just what its significance was, I am not able to say, but it is my impression that it was then more common in France (Poincaré, Abel Rey) than in Germany.

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than the rhetoric. Indeed, the rhetoric itself reacts back upon the persona of the scientist, upon his view of the conceptual situation in his science, of the extent and character of the reconstruction necessary or desirable. In fact, in this period, both mathematics and physics—but above all *German* mathematicians and physicists—went through deep and far-reaching crises, whose very definitions showed the most intimate relation with the principal currents of the Weimar intellectual milieu.

“The New Crisis in the Foundations of Mathematics” proclaimed by Hermann Weyl was precipitated virtually out of thin air in the two or three years following Germany’s defeat. With extraordinary suddenness the German mathematical community began to feel how insecure were the foundations upon which the entire structure of mathematical analysis rested, how dubious the methods by which that edifice had been erected. Now, with quasi-religious enthusiasm, considerable numbers of German mathematicians rallied to L. E. J. Brouwer’s standard calling for a complete reconstruction of mathematics, a redefinition of the enterprise, which, appropriately enough, went under the name “intuitionism.”^{137,138} The seriousness of this movement and its consequences may be judged by the vehemence of David Hilbert’s counterattack in the spring of 1922. “If Weyl notices an ‘inner untenability of the foundations upon which the construction of the empire [Reich] rests,’ and worries himself over ‘the threatening dissolution of the polity [Staatswesen] of analysis,’ then he is seeing ghosts.” Weyl and Brouwer are trying “to erect a repressive dictatorship [Verbotsdiktatur]”; to follow “such reformers” is to risk losing the most valuable treasures of mathematics. “No, Brouwer is not, as Weyl believes, the revolution, but only the repetition, with old means, of an attempted putsch . . . and now

137. H. Weyl, *Das Kontinuum* (Berlin, 1918; reprinted New York, 1962); “Der circulus vitiosus in der heutigen Begründung der Analysis,” *Jahresber. d. Dtsch. Mathematiker-Vereinigung*, 28 (1919), 85-92, reprinted in K. Chandrasekharan, ed., *Gesammelte Abhandlungen von Hermann Weyl* (Berlin, 1968), 2, 43-50; “Über die neue Grundlagenkrise der Mathematik,” *Math. Zeitschr.*, 10 (1921), 39-79, reprinted in *Ges. Abhl.*, 2, 143-180.

138. For description, bibliography, and documents of intuitionism: Abraham A. Fraenkel and Y. Bar-Hillel, *Foundations of Set Theory* (Amsterdam, 1958), especially pp. 203-204; Jean van Heijenoort, *From Frege to Gödel. A Source Book in Mathematical Logic, 1879-1931* (Cambridge, Mass., 1967); Constance Reid, *Hilbert* (New York, 1969).

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especially, with the government [Staatsmacht] so well armed and secured by Frege, Dedekind, and Cantor, condemned to failure from the start."¹³⁹

Can one read this rhetoric and not suppose that both Weyl and Hilbert at the very least saw close parallels between the crisis in mathematics and the political crises then wracking Germany, that their sense of the significance of the mathematical issues was colored by their perceptions of the political issues, that perhaps this crisis in mathematics depended for its very existence upon the social-intellectual atmosphere in the aftermath of Germany's defeat? Looking back thirty years afterward, Weyl almost conceded as much, and in fact the "crisis" itself, never resolved, eventually simply ceased to be felt.¹⁴⁰

Turning to physics one finds once again a notable internal crisis. This is the "crisis of the old quantum theory" which gripped atomic physicists—first and foremost the Germans—in the years before the introduction of the quantum mechanics in 1925/26.¹⁴¹ I have myself devoted some effort to the intriguing problem of isolating the particular difficulties and frustrations which led at a particular moment to a conviction that "the whole system of concepts

139. D. Hilbert, "Neubegründung der Mathematik. Erste Mitteilung," *Abhandlungen aus dem Math. Seminar der Hamburgischen Universität*, 1 (1922), 157-177, reprinted in Hilbert's *Gesammelte Abhandlungen*, 3 (Berlin, 1935; reprinted New York, 1965), 157-177, on 159-160. Hilbert had delivered this tirade against his most brilliant pupil as a lecture at a number of universities before printing it. And it is important to note that the adherents of the intuitionist movement not only admitted its destructive impact, but seem almost to have welcomed that consequence in a spirit of abnegation and resignation: "That proceeding from this standpoint only a part, perhaps only a wretched [kümmerlich] part, of classical mathematics is tenable is a bitter but inevitable fact." (Weyl, "Diskussionsbemerkung zu dem zweiten Hilbertschen Vortrag über die Grundlagen der Mathematik," *ibid.*, 6 [1928], 86-88, reprinted in Weyl, *Ges. Abhl.*, 3, 147-149, and translated in Heijenoort, *Source Book*, pp. 482-484.)

140. H. Weyl, "Nachtrag, Juni 1955" to "Über die neue Grundlagenkrise . . .," *Ges. Abhl.*, 2, 179: "Only with some reluctance do I acknowledge [bekenne ich mich zu] these lectures, whose occasionally quite bombastic style reflects the mood of an agitated period—the period directly after the First World War." One might even hear in Hilbert's rhetoric a quite literal warning to Weyl and his other friends against the political attitudes of the leader whom they had chosen to follow. See Schröder, *op. cit.* (note 52), pp. 219-220; Reid, *Hilbert*, p. 188.

141. Thomas S. Kuhn, "The Crisis of the Old Quantum Theory, 1922-1925," address delivered at the American Philosophical Society, April 1966. Friedrich Hund, *Geschichte der Quantentheorie* (Mannheim, 1967), p. 103.

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of physics must be reconstructed from the ground up," as Max Born asserted in the summer of 1923.¹⁴² And while it is undoubtedly true that the internal developments in atomic physics were important in precipitating this widespread sense of crisis among German-speaking Central European physicists, and that these internal developments were necessary to give the crisis a sharp focus, nonetheless it now seems evident to me that these internal developments were not in themselves sufficient conditions. The *possibility* of the crisis of the old quantum theory was, I think, dependent upon the physicists' own craving for crises, arising from participation in, and adaptation to, the Weimar intellectual milieu.

Of this predisposition to perceive the state of physics as critical, we have many examples between the summer of 1921 and the summer of 1922, which is to say in the year immediately preceding that in which the crisis of the old quantum theory was precipitated. Taking only those cases in which the crisis is proclaimed in the title itself, there is Richard von Mises's lecture "On the Present Crisis in Mechanics" of September 1921, Johannes Stark's pamphlet on *The Present Crisis in German Physics* of June 1922, Joseph Petzoldt's remarks "Concerning the Crisis of the Causality Concept" of July 1922, and Albert Einstein's popular article "On the Present Crisis in Theoretical Physics," dated August 1922.¹⁴³ Very roughly speaking each of these physicists is pointing in the same direction, viz. toward the quantum theory. There, of course, the agreement ends; each is putting his finger upon a largely, or completely, different "problem." But that very circumstance—the widespread but initially poorly focused application of the word and notion of a crisis—suggests most strongly that the crisis of the old quantum theory,

142. M. Born, "Quantentheorie und Störungsrechnung," *Naturwiss.*, 11 (1923), 537-542, quoted in my essay on "The Doublet Riddle and Atomic Physics circa 1924," *Isis*, 59 (1968), 156-174.

143. R. v. Mises, "Über die gegenwärtige Krise der Mechanik," *Zeitschr. f. angewandte Math. u. Mech.*, 1 (1921), 425-431, reprinted in *Naturwiss.*, 10 (1922), 25-29, and reprinted once again in v. Mises' *Selected Papers* (Providence, R.I., 1964), 2, 478-487, lecture, Math.-Phys. Congress, Jena, September 1921; J. Stark, *Die gegenwärtige Krisis in der Deutschen Physik* (Leipzig, 1922), 32 pp., preface dated "Anfang Juni 1922"; J. Petzoldt, "Zur Krisis des Kausalitätsbegriffs," *Naturwiss.*, 10 (1922), 693-695, dated 2 July 1922, to which Walter Schottky replied 6 October 1922 under the same title, *ibid.*, p. 982; A. Einstein, "Über die gegenwärtige Krise der theoretischen Physik," *Kaizo* (Tokyo), 4 (Dec. 1922), 1-8, dated August 1922.

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far from being forced upon the German physicists, was more than welcome to them.

And here again, as with “intuitionism” in mathematics, one cannot help but be struck by the extraordinary convenience of the chief slogan of this crisis: the failure of mechanics. However appropriate this slogan may have been as a diagnosis of the internal difficulties in theoretical atomic physics, it certainly was *most* appropriate as a code word signaling the physicists’ intent to rid their discipline of its most obnoxious elements. Conversely, the almost universal conviction among the German atomic physicists that this crisis was going to last a long, long time—although in fact it was “resolved” within two or three years by the discovery of the quantum mechanics—can be understood in part as a reluctance to contemplate giving up their fashionable and praiseworthy plight, but also in part as an expression of a Spenglerian pessimism: “in my heart I am once again convinced that this quantum mechanics”—which I, Werner Heisenberg, have just discovered—“is the answer, for which reason Kramers accuses me of optimism.”¹⁴⁴

III. “DISPENSING WITH CAUSALITY”:^{145,146} ADAPTATION OF KNOWLEDGE TO THE INTELLECTUAL ENVIRONMENT

III.1. Introduction. The Concept of Causality

Composing his article “On the Present Crisis in Theoretical Physics” for a popular audience in August 1922, Einstein began with a definition of the aim and structure of physical theory. “It is

144. “. . . mich des Optimismus anklagt. . .” W. Heisenberg to Wolfgang Pauli, 29 June 1925, as quoted by B. L. van der Waerden, *Sources of Quantum Mechanics* (Amsterdam, 1967; reprinted New York, 1969), p. 27. Heisenberg’s paper propounding this quantum mechanics, which was indeed “schon richtig,” appeared as “Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen,” *Zeitschr. f. Phys.*, 33 (18 Sept. 1925), 879–893, received 29 July 1925; it is translated in v. d. Waerden, *op. cit.*, pp. 261–276, and reprinted in M. Born, W. Heisenberg, P. Jordan, *Zur Begründung der Matrizenmechanik*, Dokumente der Naturwissenschaft, Abteilung Physik, Band 2, ed. Armin Hermann (Stuttgart, 1962), pp. 31–45.

145. This is the title of the opening chapter of Albrecht Mendelssohn-Bartholdy, *The War and German Society* (New Haven, 1937). The eminent emigré legal scholar there asserted that “War canceled causality. It seemed to do so, at least, to the German people . . . the people as a whole, regardless of their interest in politics, their state of education, or their profession and walk in life,

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the goal of theoretical physics," Einstein maintained, "to create a logical [!] conceptual system, resting upon the smallest possible number of mutually independent hypotheses, which allows one to comprehend causally [!] the entire complex of physical processes."¹⁴⁷ On the whole the conception of theoretical physics expressed by this definition is neither unfamiliar nor surprising; it was probably shared by most physicists of the period.¹⁴⁸ Yet two of Einstein's restrictions upon a physical theory seem either superfluous (of course a *logical* conceptual system, what else?) or gratuitous (why must one comprehend physical processes *causally*?). It is precisely these seemingly superfluous and gratuitous additions to what is otherwise the common creed of his colleagues which signal issues Einstein evidently regarded as crucial to theoretical physics as an enterprise. The first of these issues—a logical, as opposed to, say, an intuitive structure of physical theory—I will leave largely aside.¹⁴⁹

realize the change quite clearly, long before it could be measured by historians or sociologists" (p. 20).

146. Earlier studies touching upon the pre-1926 movement to dispense with causality: Victor F. Lenzen, "The Philosophy of Nature in the Light of Contemporary Physics," *University of California Publications in Philosophy*, 5 (1924), 27-48; Alois Gatterer, S.J., *Das Problem des statistischen Naturgesetzes*, Philosophie und Grenzwissenschaften, herausgegeben vom Innsbrucker Institut für scholastische Philosophie, 1. Band, 1. Heft (Innsbruck, 1924), 70 pp.; Stefan Kis, *Das Kausalitätsprinzip in der Physik*, doctoral diss., U. Greifswald (Greifswald, 1925), 35 pp.; Hugo Bergmann, *Der Kampf um das Kausalgesetz in der jüngsten Physik*, Sammlung Vieweg, Heft 98 (Braunschweig, 1929), 78 pp.; Philipp Frank, *Das Causalgesetz und seine Grenzen*, Schriften zur wissenschaftlichen Weltauffassung, Band 6 (Vienna, 1932); Ernst Cassirer, *Determinism and Indeterminism in Modern Physics. Historical and Systematic Studies of the Problem of Causality*, trans. O. T. Benfey (New Haven, 1956); Max Jammer, *The Conceptual Development of Quantum Mechanics* (New York, 1966).

147. A. Einstein, *op. cit.* (note 143), p. 1.

148. The conception is essentially that stated most fully and forcefully by Pierre Duhem, *La Théorie physique: son objet, sa structure*, 2nd ed. (Paris, 1914), trans. by P. P. Wiener as *The Aim and Structure of Physical Theory* (Princeton, 1954), pp. 19, 52, 107, *et passim*.

149. There are two aspects to this issue: 1) a rationalist-irrationalist opposition which is reflected in attitudes toward causality, and which I will therefore touch upon in passing; 2) an opposition, cutting across this first alignment, between intuitiveness and abstractness, *Anschaulichkeit* and *Unanschaulichkeit*, as desirable or necessary in a physical theory. The demand for *Anschaulichkeit* was, once again, very closely connected with the predilections and antipathies characteristic of the Weimar intellectual environment. This opposition played an important role in physics and mathematics in Germany in the Weimar period (see notes 235 and 237), and especially in the Nazi period. I do not, however, attempt here to deal with this difficult problem.

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It is the second issue, the “violent dispute over the significance of the law of causality”—that is the way Max Planck saw the situation in February 1923¹⁵⁰—which I will describe and analyze.

But what is meant by “causality,” or, rather, what notion did the physicists and the philosophers who stood closest to them associate with this term at this time? That notion was, in a word, lawfulness. “The principle of causality,” Moritz Schlick explained in 1920, “is . . . the general expression of the fact that everything which happens in nature is subjected to laws which hold without exception.”¹⁵¹ (Cf. Spengler’s “Causality is coextensive with the concept of law. There are only causal laws.”¹⁵²) And even ten years later Heisenberg, in his *Physical Principles of the Quantum Theory*, could still broach this question by declaring that “the resolution of the paradoxes of atomic physics can be accomplished only by further renunciation of old and cherished ideas. Most important of these is the idea that natural phenomena obey exact laws—the principle of causality.”¹⁵³ Of course Heisenberg immediately improved upon this formulation by introducing distinctions which were made and employed only after the development of quantum mechanics. In the period 1919–1925, however, both physicists and philosophers held this essentially Kantian notion of causality as conformity to law, so that, as Hans Reichenbach put it in 1920, “if there is cognition of nature, then the principle of causality is valid, for, without this principle, cognition, by its very meaning, is impossible.”¹⁵⁴

150. M. Planck, *op. cit.* (note 18), p. 140: “Seit langem ist über die Bedeutung des Kausalgesetzes in der Natur- und Geisteswelt . . . nicht so heftig gestritten worden wie in unseren Tagen. . . . Fast hat es den Anschein, als ob die denkende Menschheit bezüglich dieser Fragen in zwei getrennte Lager gespalten ist.”

151. M. Schlick, “Naturphilosophische Betrachtungen über das Kausalprinzip,” *Naturwiss.*, 8 (11 June 1920), 461-474; opening paragraph. This was still the general view five years later when *Kis* (*op. cit.*, note 146), p. 3, maintained that “Das Causalprinzip ist das Allgemeinste unter den Prinzipien der Naturwissenschaften. Es besagt, dass die Naturvorgänge nach strengen Gesetzen ablaufen, es ist mit den Worten Machs unsere Zuversicht in die Gesetzmässigkeit der Natur.”

152. Note 77. Cf. Walter Rauschenberger, reviewing Ernst Berg, *Das Problem der Kausalität* (Berlin, 1920) in *Kant-Studien*, 26 (1921), 174: “Verfasser ist also strenger Determinist. Sein Kampf gegen das Kausalitätsgesetz erscheint deshalb nicht recht verständlich. Kausalität und Gesetzmässigkeit wurden bisher stets als gleichbedeutend angesehen.” I.e., determinism = causality = lawfulness.

153. W. Heisenberg, *The Physical Principles of the Quantum Theory* (Chicago, 1930), p. 62.

154. H. Reichenbach, “Philosophische Kritik der Wahrscheinlichkeitsrech-

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But now, if such was the physicist's notion of causality, how indeed could he even contemplate dispensing with this principle? The point was made in 1924 by Alois Gatterer, philosopher and Jesuit, as "a sort of *argumentum ad hominem* which ought to give pause to especially those physicists who, like [Franz] Exner, take pleasure in trying to degrade all physical and chemical laws to statistical laws, and nonetheless at the same time, full of confidence and pride, pursue magnificent researches on the constitution of the chemical atom. How, I ask, can one approach this research with hope of success, and devote oneself actively to it, if one secretly nurtures the conviction that the elementary processes proceed, at least in part, lawlessly at random . . . ?"¹⁵⁵ Gatterer's question is a good one, and his appeal—given the physicists' own notion of causality—ought to have been a strong one; and yet, evidently, it simply was not cogent. Thus if we find physicists repudiating causality—and taking pleasure in doing so—without making any attempt to critically analyze and revise the notion itself, then I think we must construe such repudiations as directed against the sort of cognitive enterprise in which physicists theretofore had understood themselves to be engaged.

Precedents for such a reaction against the cognitive enterprise of physics do exist, and, as Stephen Brush has made us recognize, such sentiments provided much of the steam behind the positivist movement at the turn of the century.¹⁵⁶ Where Mach was content to challenge the universal validity of the laws of mechanics, the radical fringe around the positivist-monist standard advanced to the denial of *any* exact laws for atomic processes with the intent of making room for "an element of indeterminacy, spontaneity, or

nung," *Naturwiss*, 8 (20 February 1920), 146-153: "Dass eine funktionelle Form existiert, garantiert die Kausalität. . . . Allerdings ist es *denkbar*, dass das Naturgeschehen ohne funktionelle Abhängigkeiten verlief; aber wenn es eine *Erkenntnis der Natur* gibt, dann gilt das Kausalprinzip, denn ohne dieses ist Erkenntnis ihrem Sinne nach nicht möglich. . . . Wir könnten durchaus zu einer physikalischen Erkenntnis kommen, wenn das Energiegesetz nicht gilt; die Gleichungen würden dann eben anders lauten; aber ohne Geltung des Kausalgesetzes wäre Erkenntnis unmöglich, weil wir überhaupt keine quantitativen Funktionalbeziehungen aufstellen könnten."

155. A. Gatterer, *Das Problem des statistischen Naturgesetzes* (*op. cit.*, note 146), pp. 45-46.

156. S. G. Brush, "Thermodynamics and History," *The Graduate Journal*, 7 (1967), 477-565.

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absolute chance in nature,” as C. S. Peirce urged in *The Monist* in 1892.¹⁵⁷ Taking acausality in Peirce’s sense—and that is, fundamentally, the sense in which it was understood in the early 1920’s—I do not know of any other notable physicist who publically advocated this doctrine in the following quarter century, i.e., before the end of the First World War.¹⁵⁸

157. Quoted by Brush, *ibid.*, p. 531. In this, Comte’s latter day disciples were but accepting with relish what Comte believed but dreaded, namely that “the natural laws . . . could not remain rigorously compatible . . . with a too detailed investigation.” Quoted by Emile Meyerson, *Identity and Reality*, trans. Kate Loewenberg (1930; reprinted New York, 1962), p. 20. It should be noted, however, that the editor of *The Monist*, Paul Carus, was scandalized: “Mr. Charles S. Peirce’s Onslaught on the Doctrine of Necessity,” *Monist*, 2 (1892), 560-582.

158. The persistence of a subterranean anticausality current is however suggested by some public refutations of the notion in the intervening period. On 3 August 1914, addressing a founder’s day convocation at the close of his term as rector of the University of Berlin, Max Planck acknowledged that “this dualism” between causal and statistical laws which has arisen as a result of the introduction of the statistical point of view into physics “is regarded by many as unsatisfying.” Consequently attempts have been made to deny that there are any dynamical (= causal) laws whatsoever and to regard all regularity as statistical: “the concept of an absolute necessity would be lifted from physics entirely. Such a view must, however, very quickly show itself to be an error as disastrous as it is shortsighted.” (Planck, “Dynamische und statistische Gesetzmässigkeit,” *Physikalische Abhandlungen und Vorträge* [Braunschweig, 1958], 3, 77-90, on 86.) In a posthumously published contribution to the issue of *Die Naturwissenschaften* dedicated to Planck on his sixtieth birthday (23 April 1918), Marian von Smoluchowski pointed to “the tendency which holds sway today to reduce the totality of physical laws . . . to the statistics of hidden elementary events,” and he regarded it as “perfectly possible” that in time Lorentz’ theory of electrons, relativity, and the law of conservation of energy will also be subjected to this program. Yet Smoluchowski’s aim was to show that “chance—in the sense of the word ordinarily used in physics—can perfectly well result from exactly defined lawbound [gesetzmässig] causes,” and he emphasized that the calculus of probabilities is thus not to be regarded as a new principle of research but “merely a simplifying statistical schematization of certain functional interconnections which arise very frequently.” (Smoluchowski, “Über den Begriff des Zufalls und den Ursprung der Wahrscheinlichkeitsgesetze in der Physik,” *Naturwiss.*, 6 [1918], 253-263.)

Although neither Planck nor Smoluchowski identifies the physicists they mean to be refuting, it may well be that both are thinking especially of Franz Exner, whose views Smoluchowski surely knew from his years in Vienna, and Planck may have learned from Exner’s *Rektoratsrede* at the University of Vienna: *Über Gesetze in Naturwissenschaft und Humanistik. Inaugurationsrede, gehalten am 15. X. 1908* (Vienna, 1909), 45 pp. This publication, which came to my attention only after the final draft of the present essay was completed, does indeed maintain that “Alles Geschehen in der Natur ist das Resultat zufälliger Ereignisse” (p. 42), and that “if we were capable of slowing down the molecular motion so enormously that we could follow the individual molecular processes, then we would perceive nothing but a chaos of chance events, in which we would seek in vain for any regularity” (p. 13). Exner then went on to sketch a “unified

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It must, of course, be acknowledged that in precisely this period Mach himself, the positivist movement in general, and even neo-Kantians like Cassirer were waging a campaign against quite a different concept of causality, so that by 1918 Friedrich Poske could well observe that "it has recently become the fashion among those concerned with the theory of scientific method to throw the causal concept onto the scrap heap."¹⁵⁹ At issue here was not, however, the notion of conformity to law, but rather the "metaphysical," "animistic," "fetishistic" doctrine of cause and effect (*Ursache und Wirkung*) as an ontological assumption, which Mach and his allies wished to replace by the mathematical conception of function.¹⁶⁰ "This putting together of functional interconnections is what theoretical physics is really all about," Wilhelm Wien explained to a lay audience in 1914; "causality—i.e., *der Satz von Ursache und Wirkung*—has nothing to do with the business."¹⁶¹ And by 1918 this point of view had become almost a matter of course among physicists and the philosophers closely associated with them—

and comprehensive world picture" in which all law is but the expression of the law of large numbers, and the want of laws in the *Geisteswissenschaften* is due neither to the peculiar nature of their subject matter, nor to "Das Lebendige," nor to free will, but results simply from the relatively small number of equally chance events underlying the phenomena they study.

It is noteworthy, moreover, that P. Frank, *Kausalgesetz* (*op. cit.*, note 146), pp. 56-58, treated "Die energetische Naturauffassung" as one of the "Kausalitätsfeindliche Strömungen," and asserted that "at the time when the ideas of the Ostwaldian *Naturphilosophie* appeared to be dominant among those active in natural science and even among the majority of the laity interested in natural science, one could regard the notion of mechanical causality in Laplace's sense as having been disposed of, and the introduction of soul-like factors seemed necessary." This, like so much of Frank's book, is largely blather; nonetheless, it is suggestive.

159. F. Poske, *Zeitschr. f. den physikal. u. chem. Unterricht*, 31 (March 1918), 39.

160. E. Mach, *The Analysis of the Sensations*, trans. from the 5th edition, 1906, by S. Waterlow (reprinted New York, 1959), p. 81; Joseph Petzoldt, "Naturwissenschaft," *Handwörterbuch der Naturwissenschaften* (Jena, 1912), 7, 50-94, on 79-80; Paul Volkmann, *Einführung in das Studium der theoretischen Physik . . . mit einer Einleitung in der Theorie der physikalischen Erkenntnis*, 2nd enlarged ed. (Leipzig-Berlin, 1913), pp. 385-398; Ernst Cassirer, *Substance and Function*, trans. from the German edition, 1910, by W. C. and M. C. Swabey (Chicago, 1923; reprinted New York, 1953), Ch. 5; Hans Kelsen, *Society and Nature* [German title: *Kausalität und Vergeltung*]: *A Sociological Inquiry* (Chicago, 1943), p. 381.

161. W. Wien, "Ziele und Methoden der theoretischen Physik [1914]" (*op. cit.*, note 90), p. 156.

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resisted only by a few arch-reactionaries like Ernst Gehrcke¹⁶²—so that “causality,” stripped of all ontologic overtones, was taken as equivalent to functional determination. Often, but not always, causality was further specified as the “Laplacian” conception of the necessary and sufficient conditions for such complete determination, viz. a cross section of the “world” at a given moment in time;¹⁶³ such a conception followed not merely from classical dynamics but equally from the very notion of a field theory.

Beginning with causality as the postulate of the lawfulness of natural processes, we have ended with causality as rigorous determinism. One might object that there is room for several distinct positions between these two conceptions. The possibility of satisfying a (weaker) postulate of lawfulness without demanding that every detail of every natural process be unambiguously determined did not entirely escape physicists in the years before the discovery of a quantum mechanics having this general character. Nonetheless, the essential point is that in the period treated in this paper every such suggestion of a relaxation of complete determinism was advanced as, and regarded as, a failure or abandonment of *causality*. In fact, as we proceed we will occasionally find the word “causality” being used in several senses narrower than, not wider than, “determinism”—as equivalent to the laws of classical mechanics, to the conservation of energy and momentum, to visualization in space and time, to the absence of action at a distance, to action by contact, or to description by differential equations. And again, in many instances these special definitions of causality were advanced in conjunction with, and as the justification for, an assertion of the invalidity of the law of causality. In every instance, however, such special definitions of causality, and a fortiori the general requirement of unambiguous

162. E. Gehrcke, *Physik und Erkenntnistheorie*, Wissenschaft und Hypothese 12 (Leipzig-Berlin, 1921), pp. 43-51.

163. E.g., Rudolf Carnap, “Dreidimensionalität des Raumes und Kausalität,” *Annalen der Philosophie*, 4 (1924), 105-130, who, laying the groundwork preliminary to demonstrating his principal thesis that “die Dreidimensionalität des Raumes (gleichbedeutend mit der Vierdimensionalität des Weltgeschehens) ist die logische Folge der Gesetzmässigkeit des Geschehens,” notes: “Die Geltung der Kausalität im Sinne der Physik besagt: in der physikalischen Welt herrschen determinierende Gesetze, und zwar sind alle Vorgänge eindeutig bestimmt, wenn die Gesamtheit der Vorgänge eines beliebig kleinen Zeitabschnittes bestimmt ist. Die Begriffe ‘bewirken,’ ‘Ursache’ u. dgl. haben also mit dem physikalischen Begriff der Kausalität nichts zu tun.”

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determination, were held to be equivalent to the assumption of the comprehensibility of nature, and repudiated or defended as such.

III.2. The First Intimations of an Issue, 1919–1920

If one examines the annual indices to German books and periodicals in the first decades of the century, one finds a remarkable number of articles and tracts with the word “causality” in their title. Most striking, however, is the spate of such tracts in the five years 1918–1922.¹⁶⁴ Typically, these are short answers to the riddle of the universe, the revelations of enthusiasts rather than the ruminations of academics. (They show, *inter alia*, that Spengler was not alone in seeing causality as the key to that riddle.) Yet the German academics too were anxious not to be left out of this discussion; in 1915 the Prussian Academy of Sciences had offered a prize for the best history of the causal problem since Descartes, awarding it in 1919 to a devoted student of the noted determinist Benno Erdmann.¹⁶⁵

It is also at just this time—I know of no example earlier than 1919—that intimations of this issue appear in the private correspondence and public addresses of German physicists. In June 1919, replying to a lost letter from Max Born, Einstein asked ironically, “Is a hardboiled x-brother and determinist allowed to say with tears in his eyes that he has lost faith in humanity. Precisely the instinctive behavior of our contemporaries in political matters is suited to maintain a vivid belief in determinism.”¹⁶⁶ Here Einstein is, on the one hand, gently ridiculing Born for feeling sorry for himself and his country by reminding Born of the public image of the theoretical physicist—hardboiled determinist—and, on the other hand, Einstein is making a small joke which can only be to some point if it were a recognized fact that the law of causality was under attack in the social sphere and under discussion among physicists.

Einstein could still joke about the matter with Born in early

164. *Deutsches Bücherverzeichnis*, 6 (1915-1920), 770; 10 (1921-1925), 1298, lists ten such.

165. Else Wentscher, *Geschichte des Kausalproblems in der neueren Philosophie* (Leipzig, 1921), preface.

166. Einstein-Born, *Briefwechsel* (*op. cit.*, note 14), pp. 29-30.

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December,¹⁶⁷ but at the end of January 1920 his tone had become most serious, for in the meantime Born, in a long letter also lost, had evidently confessed to Einstein that he was willing to entertain the idea of acausality, supporting himself upon arguments of his subordinate, Einstein's former student, Otto Stern.¹⁶⁸ "That business of causality plagues me a great deal too," Einstein conceded, shaken by Born's defection but also anxious not to give offense by too categorical an assertion of his own "very very great reluctance to forgo *complete* causality." Yet even more interesting than these remarks themselves is the association of ideas which their precise location in Einstein's long letter—clearly a point by point reply to Born's—reveals. They occur toward the end, immediately following not unsympathetic remarks on Oswald Spengler, whose *Decline of the West*, published the year before, included barbs directed at both Einstein and Born. "Sometimes in the evening," Einstein allowed, "one likes to entertain one of his propositions, and in the morning smiles about it."¹⁶⁹

167. *Ibid.*, p. 38. Born had published a short popular exposition of general relativity, "Raum, Zeit und Schwerkraft," *Frankfurter Zeitung*, 23 Nov. 1919, Nr. 876, pp. 1-3, in which, among other jabs at Kant, he remarked that "Wer diese Entwicklung [of relativity theory] miterlebt hat, der wird sich des Zweifels am a priori-Charakter auch anderer Kategorien des Denkens nicht erwehren können." Born was then singled out for attack by Robert Drill, "Ordnung und Chaos. Beiträge zur Geschichte von der Erhaltung der Kraft," *Frankfurter Zeitung*, 30 Nov. 1919, Nr. 895, pp. 1-2; 1 Dec. 1919, Nr. 899, p. 1, a wild, fanatical Kantian who sought to prove the a priori character of the [metaphysical, ontological] concept of causality using the very concrete example of our anticipation of the taste of a piece of *Wurst*. This tickled Einstein: "Sein Nachweis der Causalität a priori ist wahrhaft erhebend."

168. Einstein to Born, 27 Jan. 1920, *Briefwechsel*, pp. 42-45. It would be most interesting to know just what Born's and Stern's views were. Some indication of them was probably contained in a talk on "Wahrscheinlichkeit und Kausalität in der Physik" which Born delivered to the Physikalischer Verein in Frankfurt on 27 July 1920 (*Jahresbericht*, 1919-1925, p. 107), but which appears to have remained unprinted.

169. Einstein, 27 Jan. 1920, *loc. cit.*: "Der Spengler hat auch mich nicht verschont. Man lässt sich gern manchmal am Abend von ihm etwas suggerieren und lächelt am Morgen darüber. Man sieht, dass die ganze Monomanie aus der Schullehrer-Mathematik kommt. Euklid-Cartesius ist sein Gegensatz, den er nun in alles hinarbeitet, aber—wie man gern zugibt—mit Geist. Solche Dinge sind amüsant, und, wenn morgen einer mit dem nötigen Geist das Gegenteil sagt, so ist es wieder amüsant, und was *wahr* ist, weiss der Teufel!"

"Spengler didn't spare me either" is a puzzle, for, so far as I can see, in the original edition (cf. note 65) relativity is handled rather unpejoratively as "die letzte Form der faustischen Natur," pp. 599-601, while Born is not mentioned

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What proposition might Einstein have had in mind? Might he not have been thinking of Spengler's most fundamental proposition, the axis of the system, "the opposition of the destiny-idea and the causality-principle"? Is the juxtaposition in Einstein's letter of Spengler's *Untergang* and the issue of causality in atomic physics pure chance? Is it not more likely that in Born's mind and/or in Einstein's mind there is an intimate, although perhaps not fully conscious, association between the physicists' new and sudden inclination to forgo causality and Spengler's enormously popular culture-criticism in which the physicist "whose entire mental existence is founded upon the principle of causality" symbolizes the late and decadent fear of the irrational, the incomprehensible?¹⁷⁰

Such an association between Spengler and the issue of acausality is certainly explicit in Wilhelm Wien's public lecture on "The Connections of Physics with Other Disciplines," which he delivered just one month later, at the end of February 1920, in the Prussian Academy of Sciences. Previously I used this lecture to illustrate a chameleonlike adaptation of the physicists' ideology to changes in the intellectual environment. Here, however, it stands as the first of a series of attempts to draw a clear line between that environment and physics as a cognitive enterprise. The apparent contradiction reflects rather the distinction I made in Part II between the peripheral and the central features of scientific ideology. Although Wien was ready to advance a new conception of the wellsprings and social-intellectual function of scientific activity designed to make the enterprise seem worthwhile in the public's eye, he was unwilling to compromise those ideological tenets which he regarded as essential to the scientific method and its cognitive goals. The true source and value of natural science lies, to be sure, in "an inner need of the human mind," but that need is for a particular kind of knowledge;

at all. It is then only in the revised edition (1923) that relativity is described as "a ruthlessly cynical working hypothesis," and the space given it much reduced, pp. 544-545 (Eng. ed., p. 419), while Born, mistaken for a chemist ignorant of mathematics, receives his just deserts in a footnote on pp. 205-206 (Eng. ed., p. 156).

170. See notes 77 and 78 and texts thereto. P. Frank, *op. cit.* (note 146), devoted a chapter to "Kausalitätsfeindliche Strömungen." He suggested that such currents were widespread in the general intellectual milieu of the Weimar period, but gave only one example: Spengler.

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it is a “longing to comprehend the causality of the course of phenomena [die Kausalität des Geschehens].”

Wien’s motivation for incorporating causality in the very definition of natural science becomes quite evident when, at the end of his lecture, he comes to the *Decline of the West*. While conceding that there is ample evidence of the accuracy of Spengler’s characterization of our present cultural situation, Wien rejects in principle the notion of historical laws, of any necessary course of history. All such laws can be and are repeatedly violated “by irrational expressions of the human spirit.” Turning Spengler against Spengler, Wien emphasizes that if we suppose a generally valid law of aging of cultures and use it to predict the future of our own, “then we reintroduce a covert causality into history.” But to adapt Kant’s well-known epigram, “I would like to assert that there is so much the more true historical science in history the less it contains of physics. . . . Causality is the foundation of the physical world picture, but it is a category [Denkform] of our mind [Geist] and cannot be employed again for the analysis of the same spirit [Geist], whose effects it is the task of history to portray.”¹⁷¹

Embracing causality in order to effect a separation between his discipline and his milieu, Wien has then the task of repulsing Spengler’s attempt to make physics culture-bound, and especially Spengler’s contention that contemporary physics, as its nerve failed, was renouncing causality. It is nature which has compelled the physicists to resort increasingly to the use of statistics; it is neither a sign of “decadence” nor of any renunciation of causality. On the contrary, every utilization of statistics “postulates causality,” but because of the great complexity the causal interconnections cannot be traced in detail. Where in 1914 Wien stressed that of all the natural sciences it is theoretical physics in which the personality has the greatest scope and importance, both in constructing theories and influencing the course of scientific development, now, contra Spengler, he is at pains to emphasize that “however strongly the shaping of physical modes of thought depends upon the constitution of the physicist, it is nonetheless decisively determined by the nature of the things themselves.” Archimedes’ results accord entirely with

171. W. Wien (*op. cit.*, note 100); the quotations are from pp. 20, 35, and 38-39, respectively.

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our own, and our results will in all probability be utilizable by physicists of a later culture.¹⁷²

The attention which Wien gives to Spengler, his focus upon the issue of causality, and his consistent effort to isolate physics—as a cognitive enterprise for which causality is the defining characteristic—from its acausal, irrational historical milieu, all suggest that he sensed an intimate connection between the treasonable murmurings against causality among his colleagues and Spengler's brilliant expression of certain powerful currents in the contemporary milieu.

III.3. Conversions to Acausality, 1919–1925

a. The Earliest Converts: Exner and Weyl

It was not until 1919, when Franz Exner was a full seventy years old, that his *Lectures on the Physical Foundations of the Natural Sciences* were printed.¹⁷³ And although the crucial concluding lectures on laws of nature may have been worked out long before in the mind and the conversation of the distinguished Viennese spectroscopist, they were probably not even included in the course as delivered to the public before the war.¹⁷⁴ The argument begins with the assertion that *none* of our laws of nature is exact. From this postulate—and here perhaps is the link with the late nineteenth-century positivist-monist repudiations of causality—Exner jumped to the conclusion that “causality” does not obtain, that if examined sufficiently closely during sufficiently short time intervals the motion of a falling body would be found to be perfectly random, directed up as often as down.¹⁷⁵ The apparent lawfulness which we discover at

172. *Ibid.*, p. 37; W. Wien, “Ziele und Methoden der theoretischen Physik. Festrede . . . 1914” (*op. cit.*, note 90), pp. 152-154.

173. F. Exner, *Vorlesungen über die physikalischen Grundlagen der Naturwissenschaften* (1st ed., Vienna, 1919; 2nd enlarged ed., Leipzig and Vienna, 1922). The crucial 86th-94th *Vorlesungen* are in all essential respects identical in both editions. The following quotations are from the preface to the first edition and from the 93rd and 94th *Vorlesungen*.

174. Internal evidence in these concluding lectures on laws of nature and Exner's reference to them in the preface as an “Anhang” argue that they were never delivered as such, but synthesized during the war when the book was written. See, however, note 158.

175. Exner claimed (86th *Vorlesung*, p. 658 in 2nd ed.) to have obtained Ludwig Boltzmann's assent to this proposition.

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the macroscopic level is then “explained” by Exner’s second thesis that all macroscopic natural laws are essentially statistical in character, the regularity arising in some unspecified way out of the collaboration of the random motions. The speculation that *all* macroscopic laws are essentially statistical, that none is exact, was by no means unprecedented. What is novel is the leap from that supposition to the conclusion that causality fails. For this leap no justification is offered, and the problem of how perfectly acausal microscopic motions result in statistical regularities is not even raised by Exner.

Exner the experimentalist takes a radical nominalist-empiricist stance: the absolutely rigorous laws “are a creation of man and not a piece of nature.” Nor have we the right to postulate even “the existence of an absolute causality,” least of all on the grounds that it is necessary in order for us to understand nature. “Nature does not inquire at all whether men understand her or not, and we are not to construct a nature adequate to our understanding, but our task is simply to come to terms with that which is given as best we can.” Although Exner cannot consistently maintain his empiricist posture and also categorically deny the existence of causality at the microscopic level, he wants very much to do so in order “to arrive at a unified world picture” in which *all* law is purely statistical, a world of pure chance. He therefore does his best to convince his (lay) readers of the implausibility of the existence of such a causal substratum, switching back and forth between, and largely confounding, the question of the validity of the laws of classical mechanics in the atomic domain and the validity of the principle of causality in the same domain.

Influential as Exner’s lectures indeed were, they have in many respects an archaic air. Exner is a curious mixture of the philosophical currents of the two preceding generations, a self-confessed mechanist-materialist yet clearly also a positivist in his view of scientific constructs. Of the *Lebensphilosophie* and existentialism which will figure so prominently in most of the following conversions to acausality there is scarcely a hint. Radioactivity and Brownian motion are the most recent developments in physics to which he refers; in his efforts to cast doubt upon the causal character of atomic processes he omits to serve himself with a “quantum” of

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any sort. Thus the first of the calls for a renunciation of causality was clearly independent of the problems raised by the quantum theory of the atom or radiation.

Apart from Exner, the earliest to speak out against causality was Hermann Weyl. Weyl was a phenomenologist of quite a different sort from his Machian ex-brothers. As Privatdozent at Göttingen shortly before the war Weyl had fallen under the influence of Edmund Husserl's program of "pure phenomenology." This Platonizing phenomenology of the mind, based upon intense introspection, had originated in epistemological concerns but in this period was degenerating into existentialism. Dating from 1917 is the first avowed intrusion of Weyl's philosophical outlook into his scientific work—his own attempt to place the continuum on an intuitionist foundation.^{176,177} But as I indicated in Section II.4, Weyl soon

176. H. Weyl, "Erkenntnis und Besinnung (Ein Lebensrückblick)," *Studia Philosophia* (1954), as reprinted in Weyl's *Ges. Abhl.*, 4, 631-649, recalled that in his student years at Göttingen, 1906-1910, his adolescent Kantianism was converted to positivism—he read Mach, Poincaré, and F. A. Lange—and only shortly before his departure for Zurich in 1913 "was it Husserl, then, who led me out of positivism to a freer view of the world once again." The contact with his colleague was mediated by one of Husserl's numerous enthusiastic students, Helene Joseph, whom Weyl married in 1913. Explicit citations of Husserl first appeared in *Das Kontinuum* (Berlin, 1918), written in 1917, and in the introduction to *Raum-Zeit-Materie*, 1st ed. (Berlin, 1918), preface dated Easter 1918. Weyl's extraordinary deference to Husserl is evident in the repeated quotations, always with full approbation, in his *Philosophy of Mathematics and Natural Science* (Princeton: Princeton University Press, 1949), translated from the German edition of 1927. In return the Husserl school was happy to lean upon Weyl and claim him for one of their own: Oskar Becker, "Beiträge zur phänomenologischen Begründung der Geometrie und ihrer physikalischen Anwendungen," *Jahrbuch für Philosophie und phänomenologische Forschung*, 6 (1923), 385-560, on 387-388. By 1928, however, the success of formalist metamathematics had shaken Weyl's allegiance: "If Hilbert's view prevails over intuitionism, as appears to be the case, then I see in this a decisive defeat of the philosophical attitude of pure phenomenology, which thus proves to be insufficient for the understanding of creative science even in the area of cognition that is most primal and most readily open to evidence—mathematics." (Weyl, *op. cit.*, note 139). See also Peter Beisswanger, "Hermann Weyl and Mathematical Texts," *Ratio*, 8 (1966), 25-45.

177. An admirable and uniquely intelligible account of this remarkable intellectual phenomenon is given by Herbert Spiegelberg, *The Phenomenological Movement: A Historical Introduction*, 2nd ed., 2 vols. (The Hague, 1965), which may be supplemented by Joseph J. Kockelmans and Theodore J. Kisiel, eds., *Phenomenology and the Natural Sciences: Essays and Translations* (Evanston, Ill., 1970).

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became the principal champion of Brouwerian intuitionism in Germany. That Weyl saw an intimate connection between intuitionism in mathematics and acausality in physics emerges quite clearly from his initial manifesto against causality, “The Relation of the Causal to the Statistical Approach in Physics,” printed in August 1920.^{178,179} “Are statistics merely a shortcut to certain consequences of causal laws,” Weyl asks, “or do they imply that no rigorous causal interconnection governs the world and that, instead, ‘chance’ is to be recognized alongside law as an independent power restricting the validity of the law? The physicists are today entirely of the first opinion.” And yesterday, in the spring of 1918, Weyl had been too, having in his proposed extension of general relativity made an “attempt,” as he admits, “at carrying through the idea of a pure

178. H. Weyl, “Das Verhältnis der kausalen zur statistischen Betrachtungsweise in der Physik,” *Schweizerische Medizinische Wochenschrift*, 50 (19 August 1920), 737-741, reprinted in Weyl’s *Ges. Abhl.*, 2, 113-122. Weyl had prepared an address with this title for a symposium on “the Significance of Probability for Natural Science and Medicine” which had been organized by Heinrich Zangger, professor of forensic medicine in Zurich, for the annual congress of the Schweizerische Naturforschende Gesellschaft in Lugano in September 1918. The congress was canceled, however, due to the grippe epidemic, so that the earliest statement we have of Weyl’s position is the 500-word abstract of the address Weyl delivered the following year, 8 September 1919; *Schweizerische Naturforschende Gesellschaft, Verhandlungen* (1919), 2. Teil, pp. 152-153. This abstract has the same general structure as the printed paper, includes Husserlian phenomenological-existentialist jargon (“das nur im Willen erlebte ‘Grund-sein,’” etc.), and concludes with an affirmation of Weyl’s belief “that at the basis of statistics there lies an independent principle which is not to be reduced to causality.” Nonetheless, it suggests very strongly that in the fall of 1919 Weyl had not yet advanced as far as his position of August 1920, and that, in particular, he had not yet made the connection with intuitionism in mathematics, the repudiation of causality and “der reinen Gesetzesphysik” being based solely upon their incompatibility with the “für unser ganzes Erleben fundamentale Einsinnigkeit der Zeit.”

179. Although he failed to mention Hermann Weyl in this connection, A. d’Abro, *Decline of Mechanism* (New York, 1939), reprinted as *The Rise of the New Physics*, 1 vol. in 2 (New York, 1952), pp. vii, 212, justified inclusion of a chapter treating “The Controversies on the Nature of Mathematics” in his historical exposition of the quantum theory on the grounds that “In our opinion these controversies originate from the same psychological differences which appear to be responsible for the current controversy concerning the principle of causality in physics.” In concluding that chapter d’Abro suggested “It might even be said that modern physics is witnessing the same crisis that we have been discussing in mathematics: the quantum theorists occupy the position of the intuitionists while Einstein and Planck occupy that of the formalists.” I think d’Abro’s conjecture is essentially correct.

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physics of law for the entirety of the world.”¹⁸⁰ But now Weyl has changed his mind and is placing himself in opposition to the prevailing opinion. Why? He has certain dissatisfactions with classical statistical mechanics and the treatment of fluctuation phenomena, but the real issue, he admits is that

finally and above all, it is the essence of the continuum that it cannot be grasped as a rigid [starr] existing thing, but only as *something which is in the act of an inwardly directed unending process of becoming*. . . . In a *given* continuum, of course, this process of becoming can have reached only a certain point, i.e. the quantitative relations in an intuitively given piece *S* of the world [regarded as a four-dimensional continuum of events] are merely approximate, determinable only with a certain latitude, not merely in consequence of the limited precision of my sense organs and measuring instruments, but because *they are in themselves afflicted with a sort of vagueness*. . . . And only “at the end of all time,” so to speak, . . . would the unending process of becoming *S* be completed, and *S* sustain in itself that degree of definiteness which mathematical physics postulates as its ideal. . . . Thus the rigid [starr] pressure of natural causality relaxes, and there remains, without prejudice to the validity of natural laws, *room for autonomous decisions* [*Entscheidungen*], *causally absolutely independent of one another*, whose locus I consider to be the elementary quanta of matter. These “decisions” are what is *actually real* in the world.¹⁸¹

I have quoted Weyl at some length, both because he goes on at some length and because a mere ascription of such radically existentialist views and motives would very likely be dismissed as incredible. Yet, clearly, these motives are primary. Weyl has resolved to abandon the ideal of a pure field physics—for which he had labored so hard and achieved such striking success—and adopted matter, or rather its free will, as the ultimate reality. The field and its laws, like geometry before Einstein, were now a mere backdrop. Why? Because it seemed necessary in order to escape the determinism which the field conception involved. Here, in the fall of 1919 and the summer of 1920 Weyl says not a word about Planck’s quantum

180. H. Weyl, *Ges. Abhl.*, 2, 116-117; “Gravitation und Elektrizität, *Preuss. Akad. der Wiss., Berlin, Sitzungsber.* (30 May 1918), 465-480, reprinted *Ges. Abhl.*, 2, 29-42, and trans., with additional notes, in H. A. Lorentz, *et al.*, *The Principle of Relativity* (London, 1923; reprinted New York, 1952), pp. 201-216.

181. H. Weyl, *Ges. Abhl.*, 2, 121-122.

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of action. It has evidently not yet occurred to him that the quantum theory could be dragged in to provide an ostensible physical basis for his existentialist repudiation of causality. It was only in the fall of 1920, when preparing the fourth edition of *Space-Time-Matter*, that Weyl seized upon the quantum theory as compelling him to say “clearly and distinctly that physics in its present state is simply no longer capable of supporting the belief in a closed causality of material nature resting upon rigorously exact laws.” There Weyl also added that crucial existentialist consideration which had been with him for some time—the repudiation of determinism restores the unidirectionality of time, “the most fundamental fact of our experience of time,” which field physics denied us a priori.¹⁸² Thus, “not only is matter restored to its old claim to reality, but also the genuine idea of causality, of *Verursachung*, as we experience it most immediately in our will, awakes to new life. Branded as fetishism by Mach . . .” etc., etc.¹⁸³

It seems pretty clear—and indeed it is characteristic of the acausalists—that the sort of primary reality which Weyl would have matter enjoy is simply not a sort of reality which is accessible to physical cognition. Thus by the summer of 1924, in carrying his “Leibnizian agent-theory of matter” to its logical conclusion, Weyl was led back to the field as the primary *physical* reality:

the material particle itself is not even a point in space, but is something entirely outside the category of extension. . . . It is analogous to the Ego, whose actions, despite the fact that it is itself nonextensional, always have their origin, through its body, at a definite place in the world continuum. Yet whatever this field exciting agent may be in its inner essence—perhaps life and will—in physics we consider it only in terms of the field actions which are excited by it and we are able to characterize it numerically (charge, mass) only by virtue of these field actions.¹⁸⁴

182. H. Weyl, *Raum-Zeit-Materie*, 4th ed. (Berlin, 1921), pp. 283-284; *Space-Time-Matter*, trans. from 4th ed. by H. L. Brose (London, 1922; reprinted New York, 1952), pp. 310-312. The preface to this edition is dated November 1920. Again, with a more precise statement of “causality,” in the 5th ed. (Berlin, 1923), pp. 286-287.

183. H. Weyl, “Feld and Materie,” *Annalen der Physik*, 65 (1921), 541-563, received 28 May 1921; reprinted in Weyl’s *Ges. Abhl.*, 2, 237-259, on 255.

184. H. Weyl, “Was ist Materie?” *Naturwiss.*, 12 (11, 18, 25 July 1924), 561-569, 585-593, 604-611; *Ges. Abhl.*, 2, 486-510, on 510.

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Weyl was now able to reconcile himself to this resurrection of the field because he thought he had finally found an escape from the proposition that the classical field theories embody and impose the Laplacian conception of causality. In a semipopular article in the form of a dialogue, Weyl argued that "according to the general theory of relativity the concept of the relative motion of several bodies with respect to one another is just as little tenable as that of the absolute motion of a single body." Consequently, the principle of causality cannot involve these untenable states of motion, and so reduces to the assertion that "the world of events only depends upon, and must be unambiguously determined by, the charge and mass of all material particles. Since this is obviously absurd . . . that principle of causality must be abandoned."¹⁸⁵

b. 1921, Summer and Fall: von Mises, Schottky, Nernst, *et al.*

The quasi-religious conversions to acausality, of which Weyl's is the earliest example, became a common phenomenon in the German physical community during the summer and fall of 1921. As if swept up in a great awakening, one physicist after the other strode before a general academic audience to renounce the satanic doctrine of causality and to proclaim the glad tidings that the physicists are about to release the world from bondage to it. The cases known to me are: Walter Schottky in June, Richard von Mises in September, Walther Nernst in October.¹⁸⁶

The conversion of von Mises to acausality is particularly interesting not only because it shows the suddenness with which this regeneration could take place and its essential independence of the difficulties encountered in atomic physics, but also because it provides *prima facie* evidence of a direct connection between the repudiation of causality by a loyal scion of Austrian positivism and

185. H. Weyl, "Massenträgheit und Kosmos. Ein Dialog," *Naturwiss.*, 12 (14 March 1924), 197-204; *Ges. Abh.*, 2, 478-485.

186. W. Schottky, "Das Kausalproblem der Quantentheorie als eine Grundfrage der modernen Naturforschung überhaupt. Versuch einer gemeinverständlichen Darstellung," *Naturwiss.*, 9 (24 and 30 June 1921), 492-496, 506-511; R. von Mises, "Über die gegenwärtige Krise der Mechanik" (*op. cit.*, note 143); W. Nernst, *Zum Gültigkeitsbereich der Naturgesetze* (Berlin, 1921), 26 pp., reprinted in *Naturwiss.*, 10 (26 May 1922), 489-495. This is Nernst's inaugural lecture as rector of the University of Berlin, 15 October 1921.

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his capitulation to the *Weltschmerz* of Spengler's *Decline of the West*. In von Mises' inaugural (and farewell) address as delivered in February 1920 at the Technische Hochschule Dresden, and as printed in August 1920, causality was still handled unself-consciously and unpejoratively as equivalent to physical explanation. "We see now in our time, how a new and simply enormous field of phenomena, the multiplicity of the chemical elements, is drawn into the realm of causal explanation." And von Mises takes it for granted that the goal of atomic physics, as of all natural science, is and must be "to explain all these phenomena on the basis of a very few principles, to reveal their causality."¹⁸⁷ But when one turns to the thoroughly Spenglerian appendix which von Mises added in September 1921 to the republication of this lecture, one finds his attitude toward causality—as toward so much else—entirely transformed. Every electrical, every thermal, every optical process is a statistical phenomenon and as such fundamentally incompatible with the concept of causality. So long as we base ourselves upon that concept "the quantum theory and everything connected therewith must appear as an insoluble riddle. Whoever traces back the history of physical cognition cannot help but recognize that here an essential *alteration of our mode of thinking*, of the entire scheme of 'physical explanation,' is inexorably demanded and is gradually being prepared."¹⁸⁸

Admittedly, von Mises has invoked the quantum theory as the occasion for the repudiation of causality. But he was not willing that it be *more* than the occasion, that, in particular, his own discipline of applied classical mechanics remain saddled with the stigma of causality. In this same month, September 1921, at the first of the annual German physics-mathematics congresses, von Mises read his colleagues a lecture—or better, made a public confession before an assembly of his peers—regarding "The Present Crisis in Mechanics."

Stated in the briefest form, this question—in whose negative answer I discern the crisis in the present state of mechanics—runs thus: can we still assume that all phenomena of motion and equilibrium which we observe in visible bodies are explicable within the framework of the

187. R. von Mises, *Naturwissenschaft und Technik der Gegenwart* (*op. cit.*, note 118), p. 19.

188. *Ibid.*, p. 30.

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Newtonian axioms and their extensions. In other words, can the temporal course of every motion of an arbitrarily delimited portion of mass be unambiguously determined by specifying the initial state and assuming some appropriate force law to be acting? . . . All that I want to try to show here is that the accumulated facts which we possess today make it evident that it is highly improbable that this goal of classical mechanics could ever be attained, and that other, perfectly definite and no longer unfamiliar, considerations are destined to relieve or to supplement the rigid causal structure [den starren Kausalaufbau] of the classical theory . . . whether the sacrifice be great or small, whether we find it difficult or easy, it seemed to me unavoidable for once clearly and frankly to state that within the purely empirical mechanics there are phenomena of motion and equilibrium which will forever escape an explanation on the basis of the differential equations of mechanics. . . .¹⁸⁹

One cannot help but be struck by the “me too” tone of von Mises’ repudiation of “the stiff causal structure” of classical mechanics and his representation of that renunciation as an act of moral virtue. Yet it is also precisely this tone which suggests that a conversion to acausality carried with it significant social approbation, social rewards so substantial that von Mises could not bear to let the atomic physicists monopolize them.

Although Weyl had already turned to the quantum theory in seeking support and ammunition for his attack on causality, Walter Schottky seems to have been the first atomic physicist to publish an acausal manifesto treating “The Problem of Causality in the Quantum Theory as a Basic Question for Modern Natural Science as a Whole.”¹⁹⁰ Schottky’s article of June 1921, subtitled “Attempt at a Popular Exposition,” is clearly an expanded version of a lecture—very likely an inaugural lecture as Privatdozent for theoretical physics at the University of Würzburg, where he had recently habilitated after several years at the research laboratories of Siemens and Halske in Berlin. Schottky feels sure that inasmuch as one is accustomed to regard the rigorous laws of physics as a model and ideal for “all analytical contemplation of nature,” a general and historical

189. R. v. Mises, *op. cit.* (note 143), *Selected Papers*, 2, 482, 487.

190. W. Schottky, *op. cit.* (note 186).

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exposition of the “crisis,” the “revolution in the basic conception of the form and range of physical laws” which is in preparation, will be welcome to his audience.¹⁹¹

In the first installment of the article Schottky builds up to the proposition that the electromagnetic field and its variables are finished, done. For, he argues with impeccable logic, if we don't know the laws of the interaction of atoms with radiation, but yet can only observe the electromagnetic field quantities through their interactions with matter, then these “state variables of the field theory . . . no longer possess any significance whatsoever for scientific research.” Allowing that “that is a consequence which to be sure thus far only very few physicists have accepted,” Schottky proceeds immediately to ask what sort of observable quantities, and what sort of connections between them, are to be put in place of the electromagnetic field. And the answer: “The law of causality itself, with its complete conditioning of the coming phenomena by the present and past phenomena, appears . . . to be placed in doubt.”¹⁹²

So much in the first installment. In the second installment we discover the conventional electromagnetic field variables and equations back at work, and all that remains of the earlier “analysis” is the insistence that any solution to the problem of the interaction of atoms and radiation must cancel causality. Schottky's first proposal is the oft-recurring conjecture that the field equations determine merely the *rate* at which the quantal elementary processes take place. But this “at first sight very attractive way is impassable,” for Einstein has told him that because of the inexact fulfillment of the conservation laws, in the course of sufficiently long times a motion with arbitrarily large velocity could arise out of nothing—a point which escaped Bohr, Kramers, and Slater three years later.

Schottky now turns to his own pet idea that there is a direct connection of the emitting with the absorbing atom by retarded action at a distance, so that at the moment when a quantum is emitted it is already predetermined where, when, and by what atom it will be absorbed. But is this not causality with a vengeance, a physics à la Calvin? That is certainly how Tetrode, an under-appreciated Dutch theoretical physicist, represented the case when, exactly one year

191. *Ibid.*, p. 492.

192. *Ibid.*, pp. 495-496.

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later, he published the outlines of a theory based upon this same conception.¹⁹³ Yet such a thought never enters Schottky's mind; all that he sees is a failure of causality arising from the fact that it is no longer possible "to conceive the course of events like a continually and uniformly flowing stream," that because the "unbreakable threads" connecting emission and absorption extend infinitely far towards past and future, it is no longer possible in principle to predict the future from a cross section of the world at a given moment in time. And finally, to make the acausality doubly sure, Schottky asserts categorically—but inexplicably—that these elementary acts of emission and absorption, the precise positions of the beginnings and ends of these unbreakable threads, are indeterminate, "without direct cause and without direct effect," "outside the relation of cause and effect."¹⁹⁴

Thus Privatdozent Schottky. Is perhaps the demonstration of the failure of causality which Geheimrat Professor Walther Nernst offered four months later in his inaugural lecture as rector of the University of Berlin—and which produced a correspondingly greater stir—less tendentious, less shallow and fallacious? Scarcely. Here again, what is most striking is the author's resolve to sink the law of causality by hook or by crook. And his motive for doing so is clear enough: "But, now, can philosophy and natural science really assert with certainty that, for example, every human action is the unambiguous result of the circumstances prevailing at the moment? If absolutely rigorous laws of nature controlled the course of all events, one would in fact scarcely be able to escape from this conclusion." But philosophy has adopted this position only because it has been tyrannized by the exact natural sciences, whose "conception of the principle of causality as an absolutely rigorous law of nature laced

193. H. Tetrode, "Über den Wirkungszusammenhang der Welt. Eine Erweiterung der klassischen Dynamik," *Zeitschr. f. Phys.*, 10 (1922), 317-328, received 14 June 1922. Tetrode is generally critical of "der einseitig gerichteten [!], zum Teil zufallsmässig bedingten Kausalität" to which the modern development of physics, above all the theory of field action, has led. But this conception of causality is not aboriginal in the human mind; therefore why not consider another conception. The result is remarkably like the Bohr-Kramers-Slater theory—the electro-magnetic field becomes unreal, the conservation of energy and momentum is statistical—but with exactly the opposite intent, namely to strengthen rather than relax determinism.

194. W. Schottky, *op. cit.* (note 186), pp. 509-511.

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the mind [Geist] in Spanish boots, and it is therefore at present the obligation of research in natural science to loosen these fetters sufficiently so that the free stride of philosophical thought is no longer hindered.”¹⁹⁵

In outline Nernst’s argument is that, first, the principle of causality implies the existence of exact natural laws, but none of the natural laws with which we are acquainted is exact, ergo it is possible, even likely, that causality does not obtain. (A debt to Exner is *not* acknowledged.) Second, even if it should be the case that the motions of individual molecules follow exact laws, we may postulate that the fluctuations in the zero-point energy of the æther disrupt these motions. As there are no experimental means for isolating a portion of the æther, the ideal of identically prepared, isolated systems is in principle unrealizable. “The law of causality demands that in the case of identical initial conditions, two different systems will follow identical courses in their changes; now, however, we conclude that two systems of this sort do not admit of being realized at all.”¹⁹⁶ Nernst is not, of course, prefiguring a quantum field theory in which the fluctuations of the æther are themselves in principle indeterminate, but rather he implicitly assumes that, as with any classical field, the time, place, and manner of such fluctuations would be completely determined if the state of the *entire* æther could be specified. This possibility Nernst can exclude only on the grounds that “then we come to an infinitely extended system, in the face of which our laws of thought fail.”¹⁹⁷

Thus it is clear that although Nernst wishes with all his heart and soul to renounce causality, he is simply unable to free himself from the implicit assumption that the world *really is* causal. Nernst himself had begun to perceive this by the spring of 1922 when his lecture was republished in *Die Naturwissenschaften*. He then added a postscript pointing out that “most religions maintain that all events

195. W. Nernst, *op. cit.* (note 186), pp. 492, 495. The following quotations are from pp. 494–495.

196. Cf. Werner Heisenberg, “Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik,” *Zeitschr. f. Phys.*, 43 (1927), 172–198, received 23 March 1927: “But in the sharp formulation of the law of causality: ‘If we know the present exactly, we can calculate the future’ it is not the conclusion but the presupposition which is false. We are unable in principle to get to know the present in all of its determinative elements” (p. 197).

197. In the original: “unsere Denkgesetze versagen.”

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occur according to the will of a most high intelligence, and thus with complete logic, which is identical to the requirement of the principle of causality." Therefore "it is obviously less a question of whether or not one regards the principle of causality as rigorously valid, but much more a question of whether one conceives the natural processes to be comprehensible or, on the contrary, holds that the human mind is incapable of following these processes down to their last details." This latter is, now, Nernst's position—"only statistical mean values of the course of events are accessible to our natural-scientific cognition"—and so we see once again that the repudiation of causality is in fact a repudiation of both reason itself and the cognitive enterprise in which physicists had theretofore been engaged.¹⁹⁸

Apart from their common theme of *ignorabimus*, the three cases just examined—von Mises, Schottky, Nernst—show a remarkable temporal coincidence, suggesting a wave of conversions to acausality. And if one recalls that there were at just this moment no specific developments in physics which could plausibly be regarded as the source of such acausal convictions, then one can scarcely escape the conclusion that what we are dealing with is, essentially, a capitulation to those intellectual currents in the German academic world which we charted in Part I. Moreover, I am inclined to regard this capitulation as a very widespread phenomenon precisely because of the lack of negative evidence. The only other general academic lecture by a theoretical physicist at this moment with which I am acquainted contains, to be sure, no explicit renunciation of the principle of causality, but the clearest indications that it is a controversial issue: upon assuming the rectorate of the University of Berne, Paul Gruner made the most strenuous efforts to hang the opprobri-

198. Nernst is really quite old fashioned in his physical conceptions, and tries only to draw modish conclusions from them. His postulate that the motions and interactions of a *sub-atomic* mechanical system (the æther) perturb those of atomic-molecular mechanical systems, so that the laws of motion of a single gas molecule would express only mean values, had been entertained by Ludwig Boltzmann a quarter century earlier—without, of course, any failure of causality having been seen therein. (Boltzmann, *Vorlesungen über Gastheorie* [Leipzig, 1896-1898], trans. by Stephen G. Brush as *Lectures on Gas Theory* [Berkeley, 1964], p. 449.) In proposing that the fluctuations of the zero-point energy of the æther are responsible for triggering the decay of radioactive atoms Nernst is, in truth, adopting a causal explanation and mechanism for this prime example of an apparently acausal natural process.

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ous epithet “causal” upon the mechanistic-materialistic world view and to sink the two together.¹⁹⁹

c. Later Notable Conversions: Schrödinger and Reichenbach

In the fall of 1921, Erwin Schrödinger came to Zurich as professor of theoretical physics at the University, and so also came into contact with Hermann Weyl. Schrödinger had earlier been in close personal contact with Franz Exner as student, assistant, and Privatdozent in Vienna before the war. And when, one year later, he delivered his public inaugural lecture, he too delivered himself of a manifesto against causality bearing much resemblance to those issued on like occasions a year earlier. Schrödinger’s manifesto, however, is distinguished not merely by its tight exposition and fine literary form, but also by its stress upon Exner’s priority and importance.²⁰⁰

The principle of causality is the postulate “that every natural process or event is absolutely and quantitatively determined at least through the totality of circumstances or physical conditions that accompany its appearance.” But “in the past four or five decades physical research has demonstrated perfectly clearly that for at least the overwhelming majority of phenomena, the regularity and invariability of whose courses has led to the postulation of general causality, the common root of the observed rigorous lawfulness is—*chance*.” Now, insofar as the physical laws are statistical, they do not *require* that the individual molecular events be rigorously causally determined. (It was “Exner who in 1919, for the first time, with complete philosophical clarity” pointed out the groundlessness of the common assumption that molecular processes are in fact causal.) Moreover, Schrödinger finds most unsatisfying the duality in the laws of nature implied by the assumption of rigorous causality in the microcosm. “In the world of visible phenomena”—governed as it is by statistics, and thus by the concept of pure number—“we have

199. P. Gruner, *Die Neuorientierung der Physik. Rektoratsrede* (*op. cit.*, note 125), pp. 5, 11.

200. E. Schrödinger, “Was ist ein Naturgesetz?” *Naturwiss.*, 17 (4 Jan. 1929), 9-11; trans. as “What is a Law of Nature?” in Schrödinger, *Science, Theory, and Man* (New York, 1957), pp. 133-147. This was Schrödinger’s inaugural lecture as professor of theoretical physics at the University of Zurich, 9 December 1922, which remained unprinted at the time.

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clear intelligibility, but behind this a dark, eternally unintelligible imperative, an enigmatic 'must.'” (Compare Spengler: “Out of the principle of causality speaks fear of the world. Into it the intellect banishes the demonic in the form of a continually valid necessity, which rigid and soul-destroying is spread over the physical world picture.”²⁰¹) “This duplication of the laws of nature,” Schrödinger continues, “reminds one too much of the animistic duplication of natural *objects* for me to believe in its tenability.” And he concludes his lecture by asserting that the solution to our difficulties in atomic physics will depend upon “liberation from the rooted prejudice of absolute causality.”

But here again the most striking features of the manifesto are, on the one hand, the quasi-moral terms in which causality—“ein dunkles, ewig unverstandenes Machtgebot”—is repudiated and, on the other hand, the frivolousness with which the objections to dispensing with causality are dismissed. And so once again there seems good reason to regard the conversion as a form of accommodation to the intellectual environment—especially good reason inasmuch as Schrödinger himself was prepared to admit the Spenglerian thesis that physical theory is an expression of, and thus conforms itself to, the *Zeitgeist*.²⁰²

I am acquainted with one further clear and dramatic example of a quasi-religious repudiation of causality in the years before quantum mechanics: Hans Reichenbach's conversion in the fall of 1925. In 1924, when he wrote his *Axiomatization of the Relativistic Theory of Space and Time*, Reichenbach still adhered firmly to the ideal of causality.²⁰³ And even as late as August, or possibly September, 1925, Reichenbach could open a popular article on “Probability Laws and Causal Laws” by asserting that the law of causality, “this supreme law,” is the precondition for the application of mathematics to physics and thus for physics to be an exact science.²⁰⁴ But the

201. See note 77 and note 158.

202. Schrödinger, *op. cit.* (notes 133, 228, and 235).

203. H. Reichenbach, *Axiomatik der relativistischen Raum-Zeit-Lehre* (Braunschweig, 1924), trans. by Maria Reichenbach as *Axiomatization of the Theory of Relativity* (Berkeley-Los Angeles, 1969), p. 15.

204. H. Reichenbach, “Wahrscheinlichkeitsgesetze und Kausalgesetze,” *Die Umschau*, 29 (3 October 1925), 789-792.

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further one reads in this article the clearer it becomes that Reichenbach's allegiance to causality is beginning to waver. "Will we one day see the old ideal of physics realized, and comprehend the atomic world perfectly rigorously? Many researchers, including the most significant, believe this. . . . Others, on the contrary, and also among them significant researchers, are of the opinion that here perhaps there is an intrinsic limit to all explanation whatsoever." And Reichenbach concludes: "One is not permitted to say that under any circumstances it must be possible to find a causal explanation at the atomic level. Rather, the decision on this question must be reserved to physics itself, and cannot be made by philosophy."

Thus far our logical empiricist Reichenbach, in August or September 1925. Consider now the paper on "The Causal Structure of the World" which the notorious existentialist Reichenbach wrote in the following month or two.²⁰⁵ The opening section—which carries a most curious subtitle: "Determinism and the Problem of the 'Now'" —begins: "It has become usual to regard the hypothesis of causality in physics as so self-evidently necessary that one no longer even thinks of subjecting it to criticism. And for the most part one does not notice at all to what a high degree this hypothesis is an extrapolation above and beyond the facts of experience. The assertion that without the hypothesis of causality no exact knowledge of nature is possible exhausts the customary defense of this standpoint." Here one searches in vain for the anticipated citation of Reichenbach's own earlier publications. "In what follows it will be shown that even without the hypothesis of rigorous causality it is possible to give a quantitative description of the course of nature which does everything that physics can possibly do. . . ." From a brief analysis of the concept of causality there then emerges very quickly, and essentially without argument, the "conclusion" that causality in the sense of determinism is an unjustified and needless extrapolation: "For physics the hypothesis of determinism is completely empty." It is therefore to be discarded, and in its place is set the concept of probability, taken as fundamental and irreducible.²⁰⁶

205. H. Reichenbach, "Die Kausalstruktur der Welt und der Unterschied von Vergangenheit und Zukunft," *Bayerische Akad. d. Wiss., München, math.-naturwiss. Abteilung, Sitzungsber.* (1925), pp. 133-175. Presented by C. Carathéodory in the session of 7 November 1925.

206. *Ibid.*, pp. 133, 136.

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What is the occasion, the motive, the driving force behind this revolution? Is it perhaps that the decision which Reichenbach the logical empiricist had reserved for physics has suddenly fallen? Of any such developments we hear not a word. Rather we are assured that "It is the demand for a minimum of assumptions which compels us to renounce rigorous causality." Which is to say that existentialist philosophy, disguised as logical empiricism, has preempted the decision. But at this point Reichenbach the existentialist strips off his disguise: various investigations, notably those of Reichenbach the logical empiricist, have shown that the idea of a causal chain is closely connected with the topology of time, that is, with the fundamental concepts "earlier," "later," and "simultaneously."

But [our existentialist Reichenbach stresses] what these investigations could not resolve is the problem of the "now" . . . the "now-point" as experience [Erlebnis] of the boundary between the past and the future. . . . An "earlier" and "later" exist also for determinism, but there is no "now"; there is no distinguishable point in time. And the feeling that my own existence is a reality, whereas Plato's life only throws its shadow into reality, must be an error. That, however, contradicts the entire orientation of our existence; we have a completely different attitude towards the future than towards the past. And unless one wants to regard every single one of our actions, every thought which accompanies us in the ordering of our daily life, as a single huge error, then determinism must be false. . . . If one renounces it, the contradiction with our elemental life-feeling can be avoided. Of course such a feeling must not be decisive if reason speaks cogently against it—let one therefore first analyze reason to see if the maintenance of determinism is necessary. And that it is not.²⁰⁷

In the suddenness of the conversion to acausality, in its explicit independence of recent developments in atomic physics, and in its perfectly manifest connection with a capitulation to existentialist *Lebensphilosophie*, Reichenbach's case is certainly extreme. Yet every one of the cases I have examined—and most especially those of Weyl, von Mises, and Schrödinger—share these characteristics to some extent. Excepting Exner, all of them have the qualities of a quasi-religious experience, of a rebirth, of contrition for past sins—in a word, of a conversion. When our converts attempted to demon-

207. *Ibid.*, pp. 138-141.

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strate the necessity for this renunciation of causality, their arguments, as often as not, ought logically to have led to the opposite conclusion. From this I think one must infer that they fully anticipated that *any* argument advanced by a physicist as a demonstration of the failure of causality would be received by their audience with uncritical applause. And when one recalls that the audiences for most of these renunciations of causality were, in the first instance, the whole body of a university assembled on a ceremonial occasion, then I think it reasonable to construe such renunciations as attempts to alter, or at least receive a special dispensation from, an unbearably opprobrious public image of the theoretical physicist as a “hard-boiled determinist.”

III.4. Unregenerates against the Tide, 1922–1923

The wave of conversions to acausality in the latter part of 1921 prompted a series of public demonstrations in support of causality by “the most significant” theoretical physicists. Planck and Einstein—Nernst’s and von Mises’ colleagues at the University of Berlin—were quite disturbed; they felt that their colleagues were (unwittingly) betraying their calling, and carrying fuel to the antiscientific fires then raging in Germany. In 1922 and 1923 they both came forward to rebuke such rashness and to defend the principle of causality in physics and beyond.

Among the first, however, to raise his voice was Mach’s old bulldog, Joseph Petzoldt, who in a long letter to the editor of *Die Naturwissenschaften* “Concerning the Crisis of the Concept of Causality” lectured Schottky and Nernst like schoolboys.²⁰⁸ The questions which they have dragged up were thoroughly considered and disposed of more than two decades ago. To Schottky he pointed out that temporal action at a distance is quite as compatible with the Machian concept of causality as is spacial action at a distance. To Nernst he declared firmly that while it is *conceivable* the regularity of nature could fail, “there is no limit to the ‘understanding’ [des ‘Begreifens’].” Only Schottky replied to Petzoldt, and his rebuttal was weak, vague, and disingenuous—“it goes without saying that the

208. J. Petzoldt, “Zur Krisis des Kausalitätsbegriffs,” *Naturwiss.*, 10 (11 August 1922), 693–695, dated 2 July 1922.

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physicists too are not glad . . . to renounce the assumption that *all* events are tied together by laws."²⁰⁹ One thus sees how little prepared the converts were to meet criticism, how disconcerting they found it, and how readily they could be silenced by it.

On 29 June 1922, some weeks before the publication of Petzoldt's letter, Max Planck, as secretary of the Prussian Academy, took the occasion of the annual public session in honor of their spiritual founder Leibniz to affirm the transcendental character of the law of causality and to reprimand academician Nernst—naturally, without naming him—for his irresponsible talk.²¹⁰ When the quantum hypothesis shall have been developed sufficiently so that one can properly speak of a quantum theory, that will be the proper moment to consider its consequences for our scientific-causal thought. "Meanwhile groping speculation offers itself the most various possibilities, whose rich profusion admonishes critical caution all the more as precisely at the present time not inconsiderable dangers to the sure advance of scientific work have arisen from various sides." Chief among these dangers is penetration by a "lively, but basically unfruitful diletantism," confusing and fusing science and religion, seeking "directly and relatively effortlessly to pluck the golden fruits of knowledge and bliss from the rich tree of life, in contrast to the so-called school or guild science, which only in hard, protracted, specialized studies is able to gather one tiny little grain after another into its barn. Today it cannot yet be foreseen when and where these colorfully iridescent foam bubbles will finally burst. . . . Vis-à-vis such intellectual currents the academies find themselves in a substantially better protected situation than their sister institutions the universities, which have to stand far more directly against the shifting surge of the waves of public life."²¹¹ Evidently then, Planck, too, saw, or at least sensed, an intimate connection between an anticausal manifesto by a rector of the University of Berlin and that constellation of attitudes which made the Weimar intellectual milieu seem to the theoretical physicist so hostile to his enterprise.

Early in the following year on 17 February 1923, Planck devoted

209. W. Schottky, "Zur Krisis des Kausalitätsbegriffes," *Naturwiss.*, 10 (1922), 982, dated 6 October 1922.

210. M. Planck, "Ansprache des vorsitzenden Sekretärs" (*op. cit.*, note 17).

211. *Ibid.*, pp. 46-48.

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an entire public lecture, again in the Prussian Academy, to a most uncompromising and courageous reaffirmation of allegiance to the principle of causality—not merely in the natural sciences, but in the *Geisteswissenschaften* too.²¹² Planck knew full well that in this “violent dispute” over causality, “splitting the intellectuals into two camps,” one of reason and one of feeling, the bulk of his audience lay within the latter camp, that much of what he said would “provoke” them and might even appear “a blasphemy, as cheap as it is intolerable.”²¹³ Nonetheless he proceeded to tell his audience that “the assumption of a causality without exception, of a complete determinism, forms the presupposition and the precondition for scientific [*wissenschaftlich*] cognition.” And anticipating precisely the issues which the uncertainty principle and complementarity were to raise, Planck knew well in advance what position he would adopt: “But has it then—one could now certainly ask—any sense whatsoever to continue speaking of a definite causal interconnection when no one in the world is capable of actually comprehending that causal interconnection as such? . . . Absolutely. . . . For causality is . . . transcendental, it is entirely independent of the constitution of the inquiring intellect, indeed it would retain its significance even in the complete absence of a knowing subject.”²¹⁴

Again in the summer of 1923 Planck took the opportunity offered by his contribution to the issue of *Die Naturwissenschaften* commemorating the tenth anniversary of the Bohr atom in order to warn his colleagues against those “eminent physicists”—unnamed, of course, but evidently Exner, Nernst, Schrödinger, and, yes, Bohr himself—“who want to allow the principles of the classical theory basically only a statistical significance. . . . Such a conception seems to me, however, to shoot far over and beyond the target, if only because with the abandonment of classical dynamics they simultaneously pull out the foundations of every rational statistics.”²¹⁵

212. M. Planck, *Kausalgesetz und Willensfreiheit* (*op. cit.*, note 18).

213. *Ibid.*, pp. 140, 160. See note 150.

214. *Ibid.*, p. 161. In his address of 3 August 1914 (*op. cit.*, note 158), pp. 78, 88-89, Planck had asserted these same propositions equally categorically but without any suggestion that his views were unwelcome to his audience.

215. M. Planck, “Die Bohrsche Atomtheorie,” *Naturwiss.*, 11 (6 July 1923, Bohr Heft), 535-537; reprinted in Planck’s *Physikalische Abhandlungen und Vorträge* (Braunschweig, 1958), 2, 543-545. Note that, like Exner, Planck, too, confuses the validity of classical dynamics in the atomic domain with the validity

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On this issue of causality Planck and Einstein were in complete agreement, and their stand together against the rising tide of acausal sentiment contributed to the preservation of a close personal bond between these two men despite the wide divergence in their political and social views. Writing to Einstein on 22 October 1921, a week after Nernst's *Rektoratsrede*, Planck, as president of the Gesellschaft deutscher Naturforscher und Ärzte for 1922, appealed to Einstein's "fine feeling for causal interconnections," and so succeeded in overcoming Einstein's resolve to boycott an organization which, he felt, had treated him meanly the previous year.²¹⁶

Apart from insisting that the adjective "causal" occupy a conspicuous place in his definitions of the goal and function of scientific activity, Einstein was not given to dogmatizing publicly and popularly on this issue.²¹⁷ His own efforts were devoted to searching in the

of causality. Bohr had recently associated himself with "the view, which has been advocated from various sides, that, in contrast to the description of natural phenomena in classical physics in which it is always a question only of statistical results of a great number of individual processes, a description of atomic processes in terms of space and time cannot be carried through in a manner free from contradiction by the use of conceptions borrowed from classical electrodynamics. . . ." ("Über die Anwendung der Quantentheorie auf den Atombau. I. Die Grundpostulate der Quantentheorie," *Zeitschr. f. Phys.*, 13 [ca. 1 Feb. 1923], 117-165, on 157; English translation in *Cambridge Philosophical Society, Proceedings* [1924], supplement, 42 pp., on 35.) It was, however, only in 1924 that Bohr spoke of "a causal description in space and time." (*Op. cit.*, note 226, p. 790.) By 1927 Bohr had ceased to regard "causal" descriptions and "space-time" descriptions as equivalent, and saw them, rather, as "complementary." (*Op. cit.*, note 241.)

216. "Es ist doch sonst bei Ihrem feinen Gefühl für Kausalzusammenhänge nicht Ihre Art, bei sachlichen Überlegungen allgemeinen Gefühlsstimmungen den entscheidenden Einfluss zu gewähren." Planck to Einstein, 22 October 1921, Einstein Collection, Institute for Advanced Study, Princeton. The experience at Nauheim, September 1920, had left a very bad taste in Einstein's mouth; nonetheless he agreed to deliver a major lecture at the following, hundredth anniversary congress in Leipzig. That summer, however, in the aftermath of Rathenau's assassination, Einstein felt compelled to withdraw from public life, and from Germany, for a time.

217. See note 147 and text thereto; cf., Einstein, "Das Kompton'sche Experiment. Ist die Wissenschaft um ihrer selbst willen da?" *Berliner Tageblatt*, 20 April 1924, Nr. 189, I. Beiblatt (Readex Microprint edition of the publications of A. Einstein, Nr. 147), where Einstein maintains that the great educational task of science "darin besteht, das Streben nach kausalem Erkennen in der Gesamtheit zu wecken und wach zu erhalten." Addressing a popular audience in June 1922 on "New Results Regarding the Nature of Light," *op. cit.* (note 135), "Einstein in conclusion gave expression to his opinion that considering the great advances in our knowledge of nature one can count upon a future solution of this problem also, and that the human consciousness possesses the necessary capabilities [Voraussetzungen] for the comprehension of the natural processes."

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field-theoretic apparatus of general relativity for a super-causal solution to the quantum problem by means of over-determined systems of differential equations.²¹⁸ Any program—e.g., Tetrode’s—to solve the problem by tightening rather than loosening the causal interconnections he greeted most enthusiastically, while efforts in the opposite direction—e.g., the Bohr-Kramers-Slater theory—he received most coolly and critically.²¹⁹ Einstein was convinced, and rightly so, that his fellow physicists were rushing to embrace a failure of causality without having made any serious attempt to explore the possibilities for a causal solution. In order to advertise this point,

218. How long had Einstein been pursuing this program? Russell McCormach, “Einstein, Lorentz, and the Electron Theory,” *Historical Studies in the Physical Sciences*, 2 (1970), 41-88, especially 83-84, raising the general problem of Einstein’s conversion to a field approach, locates that reorientation in the years 1907-1909, and sees Einstein as aiming thenceforth at “a field theory with quantum solutions, not a quantum ‘mechanics.’” Einstein’s own statements in the 1920’s of his quantum-theoretical program are quite consistent with this early date. Thus in January 1920 he wrote Born: “I believe now as before [nach wie vor] that one must seek an overdetermination by differential equations in such a way that the *solutions* no longer have the character of a continuum. But how??” (*Briefwechsel* [*op. cit.*, note 14], p. 43.) And again on 28 June 1929, receiving from Planck’s hands the second Planck Medal of the German Physical Society—the first had gone to Planck himself—Einstein implied that it had *always* been and always would be his program: “There were two ideas, especially, around which my ardent exertions grouped themselves. The evolution of the world [das Naturgeschehen] seems to be so largely determined that not only the temporal course, but also even the initial state is largely bound by law. To this idea I believed I had to give expression by finding overdetermined systems of differential equations. The postulate of general relativity as well as the hypothesis of the unified structure of physical space, or the field, were supposed to serve as guideposts in this search. There the goal stands, unattained. And there was scarcely a fellow physicist to be found who shared my hope of arriving by this route at a deeper understanding of reality. What I found on the subject of quanta are only chance insights [Gelegenheitseinsichten] or, to a certain extent, fragments, which broke off in the course of my fruitless exertions upon the great problem. I am ashamed now to receive for this so high an honor.

“Despite the fact that I believe strongly that we will not remain stuck at a sub-causality, but rather, ultimately, we will even arrive at a super-causality in the sense indicated, nonetheless I most highly admire the contributions of the younger generation of physicists which are comprised under the name “quantum mechanics,” and I believe in the deep truth-content of this theory; only I believe that the restriction to statistical laws will be only temporary.” (Einstein, “Ansprache . . . an Prof. Planck,” *Forschungen und Fortschritte*, 5 [1929], 248.)

219. Writing to Paul Ehrenfest late in August 1922 (SHQP Microfilm Nr. 1; the letter is undated), Einstein recommended “eine sehr geistvolle Arbeit von Tetrode über das Quantenproblem. Vielleicht hat er Recht; jedenfalls zeigt er sich durch diese Arbeit als Kopf ersten Ranges. Schon lange hat mich nichts mehr so elementar gepackt.” For his reactions to the Bohr-Kramers-Slater theory: Martin J. Klein, “The First Phase of the Bohr-Einstein Dialogue,” *Historical Studies in the Physical Sciences*, 2 (1971), 1-39, on 32-33.

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Einstein published in December 1923 a sketch of his own program, despite the fact that he had made essentially no progress with it.²²⁰

Altogether, were one unacquainted with the overwhelming anti-causal sentiment in the Weimar intellectual environment and the social pressures to which a physicist stepping before a general academic audience was exposed, one would have to be surprised at just how few physicists came forward to defend causality, and take issue with their colleagues who were, in fact, repudiating physics as a cognitive enterprise. It seems reasonable to suppose, however, that although few had the courage to brand themselves publicly as determinists, many a senior and influential colleague let it be known with what displeasure he viewed these capitulations to anti-scientific currents.²²¹ And such intimidation may well have been responsible for the decline in the number of full-scale manifestoes against causality by physicists after the end of 1921.

III.5. The Situation circa 1924

Although public silence seems to have been imposed fairly effectively—only in 1929 did Schrödinger allow his manifesto to be printed, while Reichenbach's was interred in the proceedings of the Munich academy—the tide against causality was not stemmed. There are numerous indications that privately the question continued to be “much discussed,”²²² and it was the impression of a contemporary

220. A. Einstein, “Bietet die Feldtheorie Möglichkeiten für die Lösung des Quantenproblems?” *Preuss. Akad. d. Wiss., phys.-math. Kl., Sitzungsber.* (13 Dec. 1923), pp. 359-364, published 15 January 1924. It must be said, however, that Einstein gave a rather different impression of the origins of his paper and his intentions in publishing it when mentioning it to H. A. Lorentz, 25 December 1923 (for source see note 114): “Ich sehe eine Möglichkeit den Quantentatsachen von der Feldtheorie aus beizukommen unter Preisgabe der mechanischen Gleichungen. Das mechanische Verhalten der Elektronen (Singularitäten) soll durch überbestimmte Feldgleichungen mitbestimmt werden. Leider sind die mathematischen Schwierigkeiten für meine Kräfte zu gross. Ich habe deshalb durch eine kurze Abhandlung das Interesse der Fachgenossen auf die Methode zu lenken versucht.”

221. For intimations of such a distaste for “polemics” see my “Doublet Riddle” (*op. cit.*, note 142), p. 171.

222. Wolfgang Pauli, “Quantentheorie,” *Handbuch der Physik*, Band 23: *Quanten* (Berlin, 1926), p. 11: the moment of transition of a single excited atom “appears, according to the present state of our knowledge, to be determined solely by chance. It is a much discussed but still undecided question whether we have to regard this as a fundamental failure of the causal description

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observer that considerable sympathy for, and more or less explicit avowals of belief in, acausality were to be met with “ever more frequently.”²²³ Where in 1922 Friedrich Poske was simply shocked by Nernst’s renunciation of causality, a year later he “warmly recommended” the second edition of Exner’s lectures.²²⁴

And in seeking the grounds for this relatively undramatic but quite definite drift away from causality circa 1924 one can finally point to specific recent developments in atomic physics. For, as I discussed in Section II.4, in 1923 and 1924 the atomic physicists were becoming convinced of the fundamental inadequacy of the extant quantum theory of the atom—which supposed classical mechanics to be valid for motions within the stationary states—and were beginning to doubt the reality of the visualizable atomic models to which that theory had been applied. I argued there that the Weimar intellectual milieu at the very least facilitated the precipitation of a generalized conviction of a crisis of the old quantum theory, and

of nature, or only as a temporary incompleteness of the theoretical formulation.” (The article was written in 1924-1925.) Compare the remarks which H. A. Kramers added in this same connection to the German translation of his popular account of the Bohr theory, originally written in Danish jointly with Helge Holst: Kramers posed for the first time the question whether the probability laws have an underlying causal mechanism or “das physikalische Kausalitätsgesetz in Wirklichkeit nicht gilt.” He then warned against stamping this latter conception as an epistemological impossibility, and added that “for the moment it is certainly rather a matter of taste which alternative one prefers, and perhaps will remain so forever. The actual choice affects the methods of physical research far less than one would at first perhaps like to believe.” (*Das Atom und die Bohr’sche Theorie seines Baues* [Berlin, 1925], p. 139. The preface is dated March 1925.)

223. A Gatterer, *op. cit.* (note 146), p. 47; also p. 36. Although Nernst seems to have refrained from printing anything further on the question, he was not entirely silent. On 11 February 1925 he delivered one of those popular lectures to the lay members of the Kaiser Wilhelm Gesellschaft which were “supposed to serve to give them an insight into the scientific work of the institutes” under the title “Causalgesetz und neuere Naturforschung.” It was noticed in the *Mitteilungen der Gesellschaft Deutscher Naturforscher und Ärzte*, 2 (April 1925), 10.

224. F. Poske, *Zeitschr. f. den physikal. u. chem. Unterricht*, 35 (July 1922), 188-189, emphasized that Nernst’s parallel between loosening of the causal principle and “certain theological doctrines . . . makes clear how earth-shattering his conception, if it were accepted, would have to be for the entire *Weltanschauung*.” In March of 1923 Poske, *ibid.*, 36, 133-134, merely described the position taken in Exner’s “especially noteworthy” final chapter, observing that “this conception is closely related to other recently expressed views according to which the role of the law of causality has been played out, and causeless chance governs.”

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I emphasized how very apt, from the point of view of an adaptation to the intellectual environment, the principal diagnosis—"the failure of mechanics"—indeed was. Yet however much this crisis and rallying cry themselves owed to precisely the same intellectual currents which were driving the reaction against causality, in the present connection the important fact is that at this moment the antimechanical and anticausal movements coalesced, reinforcing one another. The confluence and synergy of these movements appears all the more intelligible if one recalls the persistent tendency, evidenced by such diverse figures as Exner and Planck, to confuse and confound the validity of the laws of classical mechanics and the validity of the law of causality.

Now, finally, after all the posturing before popular audiences, we find the first attempts to *do* a little acausal physics. The earliest of these, appropriately enough, we owe to a quasi-crank, Hans Albrecht Senftleben. The program advanced in his paper "On the Foundation of the 'Quantum Theory'" of November 1923 included such prescient postulates as that "natural phenomena generally are to be regarded as statistical effects of totalities of elementary molecular processes which are themselves not subject to the requirement of causality," and that "Planck's constant h limits in principle the possibility of describing a process in space and time with arbitrary accuracy." Moreover, Senftleben was not entirely ignored.²²⁵

But when it comes to attention, few papers could compare with that published by Bohr, Kramers, and Slater in the spring of 1924. In January John Clarke Slater, fresh from the two Cambridges, had carried to Copenhagen a semi-deterministic space-time picture of light quanta traveling along the Poynting vector of a virtual radiation field which—and this was novel—Slater assumed to be continually emitted by atoms throughout their existence in stationary states. "When this view was presented to Professor Bohr and Dr. Kramers," Slater recalled not long afterward, "they pointed out that

225. H. A. Senftleben, "Zur Grundlegung der 'Quantentheorie,'" *Zeitschr. f. Phys.*, 22 (March 1924), 127-156, received 13 November 1923. Quotations from pp. 129-131.

Kis, *op. cit.* (note 146), discussed Senftleben quite seriously. In the summer of 1924 Kramers visited him in a sanatorium in Denmark. (Letters to Bohr and Kramers of 23 August and 8 October 1924 in the Archive for History of Quantum Physics.)

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the advantages of this essential feature would be kept, although rejecting the corpuscular theory, by using the field to induce a probability of transition rather than by guiding corpuscular quanta. . . . Under their suggestion, I became persuaded that the simplicity of mechanism obtained by rejecting a corpuscular theory more than made up for the loss involved in discarding conservation of energy and rational causation [n.b.], and the paper . . . was written.”²²⁶ And it is, I think, only by reference to the widespread acausal sentiment that one can understand the immediate and widespread assent which the theory received in Germany, even though it was in fact hardly a theory at all but rather a vague suggestion of how, renouncing causality, one might try to give a “formal” account of the interaction between atoms and radiation.²²⁷

226. N. Bohr, H. A. Kramers, and J. C. Slater, “Über die Quantentheorie der Strahlung,” *Zeitschr. f. Phys.*, 24 (ca. 20 May 1924), 69-87, received 22 February 1924, dated January 1924. The publication of the paper was probably delayed in order that it not appear earlier than the English version in the May issue of the *Philosophical Magazine*, 47 (1924), 785-802. J. C. Slater, “The Nature of Radiation,” *Nature*, 116 (1925), 278, dated 25 July 1925; quoted by van der Waerden *op. cit.* (note 144), pp. 13-14, who also reprints “On the Quantum Theory of Radiation,” pp. 159-176. The very real difference between Slater’s original notion and the view to which Bohr and Kramers persuaded him suggests a distinction between *probabilistic* and *acausal* approaches. Thus the guiding field approaches to the problem of light quanta, which had long been commonplace, and de Broglie’s suggestion of a wave as a guiding field for material particles, were probabilistic, but only by anachronistically imposing Heisenberg’s uncertainty principle can one say that they abandoned causality. Their proponents did *not* suppose it impossible to get behind these probabilities to the determinants of the individual events. An *acausal* theory, on the contrary, is one which excludes this possibility in advance. Thus the Bohr-Kramers-Slater interpretation was formed from Slater’s original proposal by precluding in principle “rational causation” in the interaction of atoms and radiation. This feature was then made more palatable by stressing the “formal character” of their description of the interaction, in contrast, one might add, with Slater’s “physical” picture.

227. Interesting for its testimony to the extent and strength of belief which the “theory” received in Germany—as for much else—is W. Pauli to H. A. Kramers, 27 July 1925 (Archive for History of Quantum Physics, SHQP Microfilm Nr. 8, Section 9): emphasizing that he does not want to be mistaken for one of the “true believers,” “Ich halte es überhaupt für ein ungeheures Glück, dass die Auffassung von Bohr, Kramers und Slater durch die schönen Experimente von Geiger u. Bothe sowie durch die kürzlich erschienenen von Compton so schnell widerlegt worden ist. Es ist zwar natürlich richtig, dass Bohr selbst, auch wenn diese Experimente nicht gemacht worden wären, nicht mehr an dieser Auffassung festgehalten hätte. Aber viele ausgezeichnete Physiker (wie z.B. Ladenburg, Mie, Born) hätten daran festgehalten und diese unglückselige Abhandlung von Bohr, Kramers und Slater wäre vielleicht für lange ein Hemmnis des Fortschrittes der theoretischen Physik geworden!”

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Certainly that same essentially moral feeling underlying Schrödinger's repudiation of causality predominated in his response to Bohr, Kramers, Slater. Having demonstrated that the "Exner-Bohr" conception of statistical conservation of energy involves an unbounded random walk of the energy content of a closed system, Schrödinger did *not* conclude that the theory is impossible, but rather, "clutching at it with both hands," he saw in it a demonstration that "a certain stability in the course of the world sub specie aeternitatis can only subsist through an *interconnection* of every individual system with the entire rest of the world. . . . Is it idle play with ideas," Schrödinger asked rhetorically, "if one is, in this connection, struck by the similarity with social, ethical, cultural phenomena?" Clearly Schrödinger thought one ought to be, and that that recognition should be decisive.²²⁸

III.6. Causality's Last Stand, 1925–1926

We are now approaching the end of the development which I have been trying to trace, that is of the rise of a will to believe that causality does not obtain at the atomic level *before* the invention of an acausal quantum mechanics. With the introduction of Heisenberg's matrix mechanics in the fall of 1925 and of Schrödinger's wave mechanics in the spring of 1926, physicists realized relatively quickly that that belief no longer had to rest primarily upon ethical considerations or to involve a purely gratuitous renunciation of the possibility of exact knowledge of atomic processes. The grounds of argument and belief were thereby substantially altered. I will not attempt here to treat the growing realization of this new situation

228. E. Schrödinger, "Bohrs neue Strahlungshypothese und der Energiesatz," *Naturwiss.*, 12 (5 September 1924), 720-724. Schrödinger, peculiarly, seems to have seen in the Bohr-Kramers-Slater proposal an attempt to rid the quantum theory of discontinuities, a goal he then pursued in and through the wave mechanics which he began to develop late in 1925 on the basis of de Broglie's ideas. Writing to Wilhelm Wien on 18 June 1926, Schrödinger observed: "Es scheint ja, dass zur Zeit nicht auf allen Seiten die Ueberzeugung besteht, dass eine Abkehr von den grundsätzlichen Diskontinuitäten unbedingt zu begrüssen ist, *wenn* es damit geht. Ich aber habe immer mit Inbrunst gehofft, dass das möglich sein wird und würde mit beiden Händen zugegriffen haben—wie ich bei Bohr-Kramers-Slater mit beiden Händen zugriff—auch wenn der Zufall nicht gerade mir selbst den ersten (mit Rücksicht auf de Broglie muss ich richtiger sagen: den zweiten) Zipfel in die Hände gespielt hätte." (Archive for History of Quantum Physics.)

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in any detail, but only emphasize once again how conscious the physicists were of the fact that they were playing before an audience hostile to causality=mechanism=rationalism, and how anxious many were to play up to that audience.

Not all, however, did so. During this period it was Wilhelm Wien who assumed again the role of champion of causality. In January 1925 he had taken his case to the general public through the pages of the Leipzig *Illustrierte Zeitung* where his denial that the quantum theory has, will, or could lead to an abandonment of the law of causality threaded its way among pictures of cabinet meetings and catastrophes, opera balls and carnival costumes. "The notion that nature is comprehensible . . . is identical with the conviction that all natural processes can be reduced to causality, to invariably valid natural laws." Of all purely philosophical notions the concept of causality has had the greatest impact on the development of humanity. It is responsible for the suppression of superstition, for modern natural science, and for the revolutions in technology and industry (n.b., the audience was nonacademic). Although the problem of the interaction of atoms and radiation "has brought all of theoretical physics into a crisis which will occupy it for a long time," the present form of the quantum theory can only be transitional, for "a statistics without a causal foundation will never be recognized by physics as something final."²²⁹

During the academic year 1925–1926 Wien fully exploited the platform available to him as rector of the University of Munich, speaking out in defense of causality in both his official addresses.²³⁰

229. W. Wien, "Kausalität und Statistik," *Illustrierte Zeitung* (Leipzig), Nr. 4169 (Feb. 1925), pp. 192, 194, 196. Max Planck was by no means silent: "Physikalische Gesetzlichkeit im Lichte neuerer Forschung," *Vorträge und Erinnerungen* (Stuttgart, 1949), pp. 183–205, especially pp. 184, 194–196; also reprinted in Planck, *Physikalische Abhandlungen* (Braunschweig, 1958), 3, 159–171. This lecture was delivered on 14 February 1926 in Düsseldorf, and again on 17 February in the Auditorium Maximum of the University of Berlin. (*Forschungen und Fortschritte*, 2 [15 March 1926], 50.)

230. W. Wien, *Universalität und Einzelforschung. Rektorats-Antrittsrede gehalten am 28. November 1925*, Münchener Universitätsreden, Heft 5 (Munich, 1926), 19 pp.; *Vergangenheit, Gegenwart und Zukunft der Physik. Rede gehalten beim Stiftungsfest der Universität München am 19. Juni 1926*, Münchener Universitätsreden, Heft 7 (Munich, 1926), 18 pp. In his one other published academic address, *Goethe und die Physik. Vortrag gehalten in der Münchener Universität am 9. Mai 1923* (Leipzig, 1923), 39 pp., on p. 5, Wien had made a point of owning his allegiance to causality: "Accustomed to seek the law of causality everywhere, the physicists ever and again give themselves great pains to uncover the reasons which led Goethe to his unfavorable attitude toward physics."

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Although his inaugural lecture of November 1925 contained no reference to the current situation in physics, Wien nonetheless took the opportunity, as we saw in Section I.1, to stress the historical importance of causality, equating it once again with the conviction that nature can be comprehended by the logical force of the human intellect, and then went on to criticize Langbehn, Chamberlain, and Spengler for their antirationalism and pessimism. The slightly equivocal tone of this lecture had, however, disappeared entirely in June 1926 when, towards the end of his term as rector, Wien spoke at the annual founder's day ceremonies on "The Past, Present, and Future of Physics," or, more accurately, on causality in the past, present, and future of physics. The theme first appears on page 4 of the printed text as the capacity of the human intellect to grasp the causality of natural processes, continues on pages 6-8 where it is emphasized that, even when the laws are statistical, causality must reign at the level of the elementary processes, and reaches a climax on pages 10 and 11 where Bohr is attacked directly and by name.

Here one must recall that, supporting himself in part upon Heisenberg's discovery of a way to do atomic physics while renouncing the goal of a detailed picture of intra-atomic motions and mechanisms, Bohr had recently been expressing far more openly and categorically his hope and belief that such pictures were impossible in principle, that physics was faced "with an essential failure of the pictures in space and time on which the description of natural phenomena has hitherto been based."²³¹ Quoting these words, Wien then sought to reprimand and silence Bohr and all others of like convictions with that same demand for self-censorship which Planck had advanced so successfully in 1922: "The physicists have always openly displayed before all the world the difficulties with which they have to contend. . . . But we must be very careful with pronouncements whose significance extends far beyond the limits of the field of physics." And Wien then went on to assert in the strongest terms that there is no physical field which is closed

231. W. Heisenberg, *op. cit.* (note 144). N. Bohr, "Atomic Theory and Mechanics," lecture at the Sixth Congress of Scandinavian Mathematicians, 31 August 1925, and revised before publication in *Nature*, 116 (5 December 1925), 845-852; reprinted in Bohr, *Atomic Theory and the Description of Nature* (Cambridge, 1934), pp. 25-51; quotation from 34-35. The German text, "Atomtheorie und Mechanik," appeared in *Naturwiss.*, 14 (January 1926), 1-10.

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to our understanding, and that physicists will not rest until they have subjected atomic processes to the law of causality.²³²

At this point, having dealt with Bohr and causality, Wien turned upon his colleague, the Professor of Theoretical Physics, Arnold Sommerfeld—without, of course, naming *him*. Although Wien had readily adapted his justifications for doing physics to the changing public values, he had nonetheless been concerned to shield the enterprise itself from the influence of the Weimar cultural milieu. Sommerfeld's "Atomistik," on the contrary, dressed up for the public with pythagorean numerical harmonies and number mysteries, was not merely an attempt to use the quantum theory to play up to the ambient antirationalism, but represented an actual research program. "The number mysticism," Wien hoped and expected, "would be supplanted by the cool logic of physical thought; not perhaps to everyone's joy. For mysticism often exerts upon many minds a greater force of attraction than the cold and sober physical mode of thought. It is far from my intent to attack mysticism as such. There are many areas of the life of the soul from which mysticism cannot be excluded; but in physics it does not belong. A physics in which mysticism governs, or even collaborates, relinquishes the ground from which it draws its strength, and ceases to deserve its name." Wien then concluded his lecture by reaffirming once again his confidence that "insight into the causal interconnections of natural processes will continue to be possible," suggesting that those who express doubts on this score are just suffering from mental exhaustion, and perhaps also on that account are inclined to harken to pessimistic words about the *Untergang des Abendlandes* or the *Zusammenbruch der Naturwissenschaft*.²³³

The confidence and corresponding aggressiveness which Wien manifested on the issue of causality in the spring of 1926 derived

232. W. Wien, *Vergangenheit, Gegenwart und Zukunft der Physik*, (*op. cit.*, note 230), p. 10. Cf. note 221.

233. *Ibid.*, pp. 15, 18. We may perhaps read this as a veiled allusion to the breakdown which Bohr suffered in 1921 and which often threatened to recur. Wien's hostility toward Sommerfeld's "Atomistik" and his aggressiveness due to confidence in Schrödinger's wave mechanics is corroborated by Werner Heisenberg's recent memoirs, *Der Teil und das Ganze: Gespräche im Umkreis der Atomphysik* (Münich, 1969), trans. [often quite inaccurately] as *Physics and Beyond: Encounters and Conversations* (New York, 1971), pp. 104-105, and 72-73, respectively.

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chiefly from Erwin Schrödinger's papers on wave mechanics which Wien was then publishing in his journal, the *Annalen der Physik*. Having repudiated causality for social-ethical reasons in 1922–1924, by the fall of 1925 Schrödinger had converted back to causality for what were most probably personal-political reasons.²³⁴ He now conceived and developed the wave mechanics as a causal space-time description of atomic processes in opposition to the Copenhagen-Göttingen matrix mechanics. To accept their contention that such a description is not possible "would be equivalent to a complete surrender." For, Schrödinger argued in February 1926 in his second paper, "we really cannot change the forms of thought, and what cannot be understood within them cannot be understood at all. There are such things—but I do not believe that the structure of the atom is one of them."²³⁵

Yet at just that moment in June 1926 when Wien, armed with Schrödinger's theory, was striking out so vigorously, the anticipated victory was being transformed into defeat by Max Born's statistical interpretation of the wave function, building an abandonment of causality right into the foundations of the wave mechanics.²³⁶ "The

234. V. V. Raman and Paul Forman, "Why Was It Schrödinger Who Developed de Broglie's Ideas?" *Historical Studies in the Physical Sciences*, 1 (1969), 291-314. A collection of seventeen letters from Schrödinger to W. Wien, December 1925–November 1927, which has recently come to light, strengthens the case advanced in that publication. Xerox copies of these letters have been deposited in the Archive for History of Quantum Physics.

235. E. Schrödinger, "Quantisierung als Eigenwertproblem (Zweite Mitteilung)," *Ann. d. Phys.*, 79 (April 1926), 489-527, reprinted in Schrödinger, *Die Wellenmechanik*, Dokumente der Naturwissenschaft, Abteilung Physik, Band 3, ed. Armin Hermann (Stuttgart, 1963), pp. 25-63; on 509 and 45, respectively. A partial, and occasionally quite erroneous, translation is included in Gunther Ludwig, *Wave Mechanics, Selected Readings in Physics*, ed. D. ter Haar (Oxford, 1968), pp. 106-126, on 120-121.

On 25 August 1926, Schrödinger wrote W. Wien that: "Ich möchte aber heute nicht mehr gern mit Born annehmen, dass solch ein einzelnes Ereignis [e.g., the interaction of an electron with an atom] 'absolut zufällig' d.h. vollkommen untermi- niert ist. Ich glaube heute nicht mehr, dass man mit dieser Auffassung (für die ich vor vier Jahren sehr lebhaft eingetreten bin) viel gewinnt. . . . Bohrs Standpunkt, eine räumlich-zeitliche Beschreibung sei unmöglich, lehne ich a limine ab. Die Physik besteht nicht nur aus Atomforschung, die Wissenschaft nicht nur aus Physik und das Leben nicht nur aus Wissenschaft. Der Zweck der Atomforschung ist, unsere diesbezüglichen *Erfahrungen* unserem übrigen Denken einzufügen. Dieses ganze übrige Denken bewegt sich, soweit es die Aussenwelt betrifft, in Raum und Zeit." (Archive for History of Quantum Physics.) One thus meets once again (cf. note 228) Schrödinger's insistent demand that scientific views conform with world views.

236. Max Born, *Zur statistischen Deutung der Quantentheorie*, Dok. der Naturwiss., Abt. Physik, Bd. 1, ed. Armin Hermann (Stuttgart, 1962).

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true state of affairs,” Heisenberg declared in the spring of 1927, “can be characterized thus: Because all experiments are subject to the laws of quantum mechanics, . . . quantum mechanics establishes definitively the fact that the law of causality is not valid.”²³⁷ And once again, when one sees how rapidly this failure of causality was accepted by physicists not merely as a definitive feature of the theory, but equally of reality, one can scarcely escape the conclusion that such a result, far from being regretted, was greeted with relief and satisfaction. The atomic physicists had fulfilled the obligation which Nernst—and their social-intellectual milieu—had laid upon them.

That conclusion is surely also suggested by the physicists’ general anxiousness to carry the good news to the educated public—Heisenberg published a popular article retailing his conclusions even before his “technical” paper was printed²³⁸—but also from the terms

237. W. Heisenberg, “Über den anschaulichen Inhalt . . .,” (*op. cit.*, note 196), p. 197, received 23 March 1927. A full year earlier Senftleben, *Physikal. Berichte*, 7 (April 1926), 520, had pointed to Heisenberg’s paper initiating the matrix mechanics (*op. cit.*, note 144) as an example of the recent tendency to accept “to a certain degree” the view he had advanced in 1923 (*op. cit.*, note 225). Presumably Senftleben would have regarded the principle of indeterminacy which Heisenberg now propounded as merely the consummation of that process of acceptance of his own views.

238. W. Heisenberg, “Über die Grundprinzipien der ‘Quantenmechanik,’” *Forschungen und Fortschritte*, 3 (10 April 1927), 83: “so scheint durch die neuere Entwicklung der Atomphysik die Ungültigkeit oder jedenfalls die Gegenstandslosigkeit des Kausalgesetzes definitiv festgestellt.” Considered biographically, this enthusiasm is not unexpected. Heisenberg stresses repeatedly in his memoirs (*op. cit.*, note 233) that when he entered upon the study of theoretical physics at the University of Munich in the Fall of 1920 he had been active in the German *Jugendbewegung* for some years, and he continued so for some years afterward. Although Heisenberg is studiously vague about the particular organization in the politically variegated youth movement to which he belonged—W. Z. Laquer asserts that Heisenberg was a *Weisser Ritter*, and the following observations are especially applicable to this generally rightist group—the intellectual orientation of the movement as a whole has been well characterized by Theodor Wilhelm: “the *Jugendbewegung* is firmly and deeply embedded in that glorification of undivided life, which was intoned by Nietzsche, systematized in the *Lebensphilosophie* of the beginning of the century, paraphrased by the movements for reform in art and pedagogy, and from which the Hitler movement, too, profited in its own way.” In fact it was the most radical antagonists of the exact sciences among the vulgar *Lebensphilosophen*—Ludwig Klages, Hermann Keyserling, Rudolf Steiner—who had the greatest following and exerted the strongest influence within the *Jugendbewegung*. Laquer quotes the leader in charge of the youth movement’s career counseling office—never mind that he was a communist—contending in November 1918 that some professions were “without value for our future community and its plans to conquer the world”; heading that list was, naturally, physics, followed by chemistry, medicine, and engineering.

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in which they presented these glad tidings. In a public lecture at the University of Hamburg early in 1927 Arnold Sommerfeld raised "the question which is discussed so much these days, whether the rigid pattern [starre Form] of causality which we have inherited from the 18th century"—read enlightenment, utilitarianism, materialism, etc.—"and from the rationalistic science of mechanics, is appropriate to our contemporary body of experience."²³⁹ And when the question is posed in this form there is no doubt either about the answer which his audience wished to hear. Or again, consider

Although this orientation is never permitted to appear explicitly in Heisenberg's memoirs, it may be read between the lines. Thus Heisenberg represents himself (pp. 19, 27) as being forced to defend his decision to make a career of theoretical physics—which, interestingly, he claims to have done on the grounds that theoretical physics has "thrown up problems that challenge the whole philosophical basis of science, the structure of space and time, and even the validity of causal laws." Refusing to choose between theoretical physics and the *Jugendbewegung*, during his first two years at the University Heisenberg divided himself between "two quite different worlds. . . . Both worlds were so filled with intense activity that I was often in a state of great agitation, the more so as I found it difficult to shuttle between the two." The nature and intensity of that agitation becomes clearer if one recalls, on the one hand, that the youth movement organizations of the Weimar period, the *Bünde*, unlike present or Anglo-Saxon organizations, demanded a total commitment—as Theodor Wilhelm says, "Man verschrieb sich seinem Bund ganz"—and also notes, on the other hand, that Heisenberg's monitor in his second world, Wolfgang Pauli, was the very epitome of all that the youth movement detested: unathletic, hedonistic, indifferent to nature, addicted to urban night life, sarcastic, cynical, incisively critical, and Jewish to boot. (Walter Z. Laquer, *Young Germany: A History of the German Youth Movement* [New York, 1962], pp. 34, 102, 116, 141; Theodor Wilhelm and Wilhelm Ehmer in Werner Kindt, ed., *Grundschriften der deutschen Jugendbewegung* [Düsseldorf-Köln, 1963], pp. 12, 232.)

239. A. Sommerfeld, "Zum gegenwärtigen Stande der Atomphysik. Vortrag, gehalten auf Einladung der naturwissenschaftlichen Fakultät zu Hamburg," *Physikalische Zeitschr.*, 28 (1927), 231-239, received 18 February 1927, reprinted in Sommerfeld's *Gesammelte Schriften* (Braunschweig, 1968), 4, 584-592, on 588. In the pre-quantum mechanical period, too, although never willing to renounce the full and unique determination of physical processes, neither could Sommerfeld resist the temptation to play up to the anticausal sentiments of a popular audience. Thus in addressing a general session at the Innsbruck Naturforscherversammlung, September 1924, he passed over the use of transition probabilities, the Bohr-Kramers-Slater paper, etc., without comment, but took the structure of the semi-empirical formulas for the relative intensities of spectral lines as the occasion for opening the prospect of a "teleologische Umbildung der Kausalität." Sommerfeld, "Grundlagen der Quantentheorie und des Bohrschen Atommodells," *Naturwiss.*, 12 (21 November 1924), 1047-1049; *Ges. Schr.*, 4, 535-543. Cf. note 31 and text thereto.

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the terms in which Max Born discussed the same question in the *Vossische Zeitung*, Berlin's highbrow liberal newspaper, in the spring of 1928. After defining causality as determinism, and adding that all previous laws of physics had that characteristic, Born observed that "such a conception of nature is deterministic and mechanistic. There is no place in it for freedom of any sort, whether of the will or of a higher power. And it is that which makes this view so highly valued by all 'good rationalists.'" But happily physics has now discovered new laws which give it an entirely different character.²⁴⁰ That character, Bohr had stressed repeatedly in his lectures at Como and at the Solvay Congress the previous fall, is an "inherent 'irrationality'"; indeed "the inevitability of the feature of irrationality characterizing the quantum postulate" was accepted most willingly by Bohr, who showed no sympathy for

240. M. Born, *Vossische Zeitung*, 12 April 1928, as quoted at length by H. Bergmann, *Der Kampf um das Kausalgesetz* (*op. cit.*, note 146), pp. 34-37. Born is reviewing Emanuel Lasker's *Die Kultur in Gefahr* (Berlin, 1928), 64 pp. Lasker, himself much provoked by the professional physicists over the theory of relativity, adopted a very provocative tone: "The old axiom 'from nothing comes nothing' is refuted by the new discovery that the principle of causality is not valid. It's hard to say from whom the genial notion came. Inspired by the spirit of the age of c [the velocity of light] the prophets of the new doctrine had this bright idea which is destined to make world history. Long it grew in secret, carefully weighed and considered, until it has now celebrated in the *Handbuch der Philosophie* [i.e., Weyl, *op. cit.*, note 177] its entrance into the realm of science. . . . The new result runs: in physics and chemistry the principle of causality holds only probably. The old idea of the necessity, unambiguity, and regularity of the laws of nature is ridiculous. The pattern for a law of nature is the lottery. Until further notice. It depends upon what we decide. We believe in principle in the power of experiment. Our council decides the meaning of the experiment—by majority decision. . . . Unfortunately there are a few experimentalists who don't understand the meaning of their own experiments. They still struggle for the old, outmoded view. Rigid habits of thought! The interpretation of an experiment is reserved solely to those who understand experiments and at the same time have a high flying, world embracing imagination. The opinion of those who do not satisfy both these conditions doesn't count. The physicist who is content to measure remains an artisan. He becomes an artist only when he is also a philosopher. The philosopher in turn is negligible if he isn't stamped as an experimental physicist. The physicist-philosopher alone is permitted to interpret and evaluate experiments. . . . The true instrument of the physicist-philosopher is illumination. . . . We are prepared to debate with anyone who is both physicist and philosopher and accepts our methods. To debate with other people would be a waste of time, and we have quite enough work to do turning science into new pathways. Just at this moment we have our hands full replacing the principle of causality by another which we will postulate, and which we will then impose upon the philosophers" (pp. 20-22).

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Schrödinger's attempt "to remove the irrational element expressed in the quantum postulate."²⁴¹

It is true that Sommerfeld himself, even as he raised the question of "the rigid pattern of causality," stressed that it was not his intent to call into question "the lawlike definiteness of the physical processes," and elsewhere, as we saw in Section I.1, was at this time actually writing against the less academic forms of the contemporary romantic reaction. But it seems to me that this circumstance only strengthens the inference that an acausal quantum mechanics was particularly welcome to the German physicists because of the irresistible opportunity it offered of improving their public image. Now they too could polemicize against the rigid, rationalistic concept of causality and hope to recover lost prestige thereby.

III.7. Conclusion

In an interview with Einstein in 1932, James Gardner Murphy, an Irish literary man with wide acquaintance among the German theoretical physicists, remarked that "it is now the fashion in physical science to attribute something like free will even to the routine processes of inorganic nature." "That nonsense," Einstein replied, "is not merely nonsense. It is objectionable nonsense. . . . Quantum physics has presented us with very complex processes and to meet them we must further enlarge and refine our concept of causality." Murphy: "You'll have a hard job of it, because you'll be going out of fashion . . . scientists live in the world just like other people. Some of them go to political meetings and the theater and mostly all that I know, at least here in Germany, are readers of current literature. They cannot escape the influence of the *milieu* in which they live. And that *milieu* at the present time is charac-

241. N. Bohr, "The Quantum Postulate and the Recent Development of Atomic Theory," *Nature*, 121 (14 April 1928), 580-590, reprinted in Bohr, *Atomic Theory and the Description of Nature* (Cambridge, 1934), 52-91, on 580, 586, 590, and 54, 75, 91, respectively; German translation in *Naturwiss.*, 16 (1928), 245-257. Cf. Philipp Frank, "Gibt es ein irrationales Moment in den Theorien der modernen Physik?" *Neue Zürcher Zeitung* (17 December 1928), Nr. 2355, who is at pains to combat this notion which had already been seized upon gleefully by Adolf Koelsch, "Die Verpersönlichung des Elektrons," *ibid.* (20 October 1928), Nr. 1910.

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terized largely by a struggle to get rid of the causal chain in which the world has entangled itself.”²⁴²

Murphy’s assertion of the inescapability of the influence of the milieu is the more worthy of our attention as it is but a paraphrase of a passage from a lecture by Schrödinger, “Is Natural Science Conditioned by the Milieu?,” published earlier that year.²⁴³ Murphy’s own contribution is the specific identification of hostility toward causality as the dominant characteristic of the contemporary milieu, and the implication that the scientist’s attitude toward this particular concept had virtually been determined thereby.

Schrödinger’s and Murphy’s analysis is, as the foregoing investigation has shown, remarkably accurate, at least for the German-speaking Central European physicists. Their craving for crises, their readiness to adapt their ideology to the values of their social-intellectual environment argue a substantial and largely indiscriminate participation in the attitudes of their academic milieu, a readiness to swim along in the intellectual currents of the day. This circumstance is the more surprising if one bears in mind that the values characteristic of these intellectual currents which set in so strongly after Germany’s defeat were fundamentally antithetical to the scientific enterprise. Indeed the mathematical physicist, the personification of analytical rationality, was often singled out as the prime exemplar of a despicable way of grasping the world. Above all, with astonishing unanimity, it was the physicist’s attempt to subject the world to the rigid, dead hand of the law of causality—to use the rhetoric Spengler made so popular—which was taken to epitomize all that was most detestable in the scientific enterprise. These two circumstances—hostile environment and accommodation to its values—were then found to be linked by much direct and indirect evidence suggesting that the accommodation was in response to the hostility. Stated in terms of Karl Hufbauer’s distinctions: suddenly deprived by a change in public values of the approbation and prestige which they had enjoyed before and during World War I, the German physicists were impelled to alter their ideology

242. “Epilogue: A Socratic Dialogue. Planck-Einstein-Murphy,” in Max Planck, *Where Is Science Going?* trans. James Murphy (New York, Norton, 1932), pp. 201–221, on 201–205.

243. Schrödinger, *op. cit.* (note 143).

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and even the content of their science in order to recover a favorable public image. In particular, many resolved that one way or another, they must rid themselves of the albatross of causality.

In support of this general interpretation I illustrated and emphasized the fact that the program of dispensing with causality in physics was, on the one hand, advanced quite suddenly *after* 1918 and, on the other hand, that it achieved a very substantial following among German physicists *before* it was "justified" by the advent of a fundamentally acausal quantum mechanics. I contended, moreover, that the scientific context and content, the form and level of exposition, the social occasions and the chosen vehicles for publication of manifestoes against causality, all point inescapably to the conclusion that substantive problems in atomic physics played only a secondary role in the genesis of this acausal persuasion, that the most important factor was the social-intellectual pressure exerted upon the physicists as members of the German academic community.

And here, saving perhaps the case of Hermann Weyl, it was not a question of "philosophical" influences in any serious intellectual sense. By far the single most influential "thinker" was Spengler, and that only because the *Untergang des Abendlandes*, the concentrated expression of the existentialist *Lebensphilosophie* that was diffused through the intellectual atmosphere, was read with attention by most German mathematicians and physicists on account of the prominent role Spengler had given their sciences. Thus, excepting Franz Exner, the philosophical theses of the latter nineteenth century to which Jammer has drawn attention, while they may perfectly well have some ultimate responsibility for the ideational content of the *Lebensphilosophie* of the Weimar period, played, *per se, an sich*, a negligible role in the sudden rise of anticausal sentiment among German physicists after the First World War. Rather, it was only as and when this romantic reaction against exact science had achieved sufficient popularity inside and outside the university to seriously undermine the social standing of the physicists and mathematicians that they were impelled to come to terms with it.

There are, moreover, many indications that this accommodationist strategy met with considerable success. The "objectionable nonsense" about the free will of electrons which philosophers, aided and abetted by physicists, were talking in the late 1920's, constituted in

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fact a very favorable press. Although distasteful to Einstein, this image of modern physics was exactly suited to the taste of the educated public of the Weimar period. And I would emphasize that much of the nonsense announced with great fanfare by philosophers in the late 1920's owed nothing whatsoever to the quantum mechanics discovered in 1925–1926, but was based wholly and solely upon the manifestoes against causality issued by physicists before that date. Such, for example, were the articles which Ludwig von Bertalanffy published in 1927 gloating over the fact that “in physics itself views are coming to be accepted which in biology would be designated as vitalistic. . . . The causal world picture of the physicist is dissolving—into its place steps one which recognizes individuality, even for the molecular process. . . . Indeed that allusion of Nernst's to the freedom of will of the theologians can even be employed to support one of Spengler's most controversial ideas: that modern physics, renouncing rigorous causality and exact laws of nature, will give way to a new mysticism.”²⁴⁴

244. L. v. Bertalanffy, “Über die Bedeutung der Umwälzung in der Physik für die Biologie,” *Biologisches Zentralblatt*, 47 (Nov. 1927), 653-662; on 653-656. Likewise, Bertalanffy, “Über die neue Lebensauffassung,” *Annalen der Philosophie*, 6 (Sept. 1927), 250-264. A somewhat more delicate picture, again based solely upon pre-1925 sources, was painted by Karl Joël, “Überwindung des 19. Jahrhunderts im Denken der Gegenwart,” *Kant-Studien*, 32 (1927), 475-518, especially 482-487.

Not every *Lebensphilosoph* reacted in this way; in fact it appears that many a transcendental idealist, *lebensphilosophisch*-existentialist academic philosopher resented the attempts of the physicists to escape from the stocks of causality and usurp their role of national *Seelsorger*. A very early example is Kurt Riezler who in 1923 noted that recent developments in physics “have induced a number [*Reihe*] of natural scientists to express the hope, or at least to hint, that utilizing these and perhaps other discoveries still to be made the concept and the range of validity of natural laws will be transformed in such a way as would allow the bridge from natural processes to historical processes to be espied, and the gulf which appears to separate necessity and freedom to be closed.” Riezler aims, therefore, “to probe the question whether, how far, and by what route that bridge to the world of the spirit and of freedom, which some natural scientists believe they espy, can and may be sought.” His conclusion is that the cobbler should stick to his last, that “the second presupposition of natural science, determination, is likewise invariable. The natural scientist—[Nernst cited here]—who wants to see ‘the bands of the law of causality’ loosened, saws off the branch upon which he sits,” while the philosopher on the contrary is not restricted to so narrow a conception of the world. (“Über das Wunder gültiger Naturgesetze. Eine naturphilosophische Studie,” *Dioskuren: Jahrbuch für Geisteswissenschaften*, 2 [1923], 238-274, on 238, 257.) By 1925, however, Riezler was no longer quite so categorical: “Die Hypothese der Kausalität,” *Die Akademie: eine Sammlung von Aufsätzen aus dem Arbeitskreis Erlangen 4* (1925), 116-146, esp. 143.

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One must admit that Bertalanffy's equation of the renunciation of causality with mysticism is not wholly unjustified. For as we saw, the manifestoes by physicists against causality before 1925 were issued not in spite of, but much rather because of, the general belief that "an abandonment of determinism would signify a renunciation of the comprehensibility of nature." Far from engaging in any critical analysis of the concept of causality, directed toward the relaxation of determinism without renouncing *a priori* the comprehensibility of nature, these physicists actually reveled in that consequence, stressed the failure of analytical rationality, implicitly repudiated the cognitive enterprise in which physics had theretofore been engaged.²⁴⁵

For this reason the acausality movement could not but arouse opposition within the German physics community. Indeed one has here the most characteristic difference between those physicists who hastened to renounce causality and those who clung to it even after the discovery of quantum mechanics. For Exner, Schottky, Nernst, and Bohr the failure of causality was essentially a failure of the human intellect; Weyl, von Mises, and Reichenbach went even further, expressing an existentialist revulsion against intellectuality. On the other hand those few physicists—strikingly and significantly few—who came forward to publicly oppose dispensing with causality all based their cases upon the value of rationality and their faith in the capacity of the human intellect to comprehend the natural world: so Einstein, Petzoldt, Planck, Schrödinger (after his reconversion), and W. Wien (*vis-à-vis* inorganic nature). And for this reason also I have not been able to, nor indeed wished to, maintain a perfectly neutral stance in my exposé. Although a readiness to view atomic processes as involving a "failure of causality" proved to be, and remains, a most fruitful approach, before the introduction of a rational acausal quantum mechanics the movement to dispense with

245. The quotation is from S. Kis, *op. cit.* (note 146), p. 33. The first serious attempt to reanalyze the concept of causality in order to determine just how much of it is required for the comprehensibility of nature appears to be Eino Kaila, *Der Satz vom Ausgleich des Zufalls und das Kausalprinzip. Erkenntnislogische Studien* (Turku [Åbo], 1924 = *Annales universitatis fennicae Aboensis*, Series B, Tom. 2, No. 2), to which we may perhaps add Reichenbach's, *op. cit.* (note 205).

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causality expressed less a research program than a proposal to sacrifice physics, indeed the scientific enterprise, to the *Zeitgeist*. My sympathies have consequently been with the conservatives in their defense of reason, rather than with the “progressives” in their denigration of it.

But if this social-intellectual phenomenon is to be comprehended, in part at least, by means of a dichotomy between progressives and conservatives, then correlations might be anticipated between a physicist’s position on the causality issue and his general intellectual-political orientation. And in fact, paralleling Ringer’s observation that early in the Weimar period the “modernist” academics tended to be “methodologically adventurous,” one finds that, by and large, those physicists who were readiest and earliest to repudiate causality had either distinctly “progressive” political views by the standards of their social class and the German academic world, and/or had an unusually close interest in, or contact with, contemporary literature. Nernst, who in his youth had wished to become a poet and who retained his interest in literature throughout his life, was also one of the few German physicists who publicly associated themselves with the cause of parliamentary democracy. Von Mises, although politically conservative and nationalistic, was on his way to becoming the foremost authority on the young Rilke. Born and Weyl were both well disposed toward the German republic, at least at its birth—in itself a sufficiently unusual sentiment in the German academic world—and both had literary wives. On the other hand, with the notable exception of Einstein, those who defended causality tended to be highly principled political conservatives and/or interested in classical literature. Such were Planck, Schrödinger, and Max von Laue—who kept their knowledge of Greek well polished. Standing to their right was W. Wien. And finally to the causalist camp one may add the outright reactionaries: Ernst Gehrcke, Erwin Lohr, Philipp Lenard, and Johannes Stark.²⁴⁶

246. F. A. Lindemann and F. Simon, “Walther Nernst, 1864-1941,” *Obituary Notices of Fellows of the Royal Society of London*, 4 (1942), 101-112. Nernst had subscribed to a manifesto in the summer of 1917 calling for democratic political reforms in Prussia, and he had participated in the 1926 meeting of republican-parliamentary university professors: Klaus Schwabe, *Wissenschaft und Kriegsmoral: Die deutschen Hochschullehrer und die politischen Grundfragen des*

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This very circumstance—that the alignment within the German physics community over the issue of causality correlates closely with the intellectual and political temper of the individual physicist—reminds us, however, that the “sociological” model employed in this paper cannot be the whole truth. It provides a general framework, and seems to work especially well in certain extreme cases. But in order to account for its special applicability to some physicists and its special inapplicability to others one must invoke precisely those factors which are excluded from the model—individual personality and intellectual biography. The mechanism advanced for the entrainment of the German physicists and mathematicians by the *Zeitgeist* is thus clearly not sufficient. And it may be that

Ersten Weltkrieges (Göttingen, 1969), p. 264, note 229; Wilhelm Kahl, *et al.*, *Die deutschen Universitäten und der heutige Staat: Referate erstattet auf der Weimarer Tagung deutscher Hochschullehrer am 23. und 24. April 1926* (Tübingen, 1926), pp. 38-39. Von Mises' nationalistic attitudes are reflected in his repeated promotion of political boycotts by German scientists of international congresses. For example: Th. von Kármán to von Mises, 11 December 1923, and P. Debye to von Kármán, 1 May 1926, in the Kármán Papers, California Institute of Technology Archives, but especially the correspondence between von Mises and L. E. J. Brouwer in 1928 in the von Mises Papers, Niels Bohr Library, American Institute of Physics, New York. There are many indications of Max Born's political attitudes in his correspondence with Einstein (*op. cit.*, note 14), where specimens of Hedwig Born's poetry are also published. Hermann Weyl's initial attitude toward the German republic may be glimpsed in a letter to Einstein of 16 November 1918 in the Einstein Collection, Institute for Advanced Study, Princeton, and in the Weyl Nachlass, Bibliothek der Eidgenössischen Technischen Hochschule, Zurich; his continuing attachment to democracy is suggested in the talk by which he introduced himself to the Göttingen mathematics students in 1930, quoted at length in his “Rückblick auf Zürich aus dem Jahre 1930,” *Schweizerische Hochschulzeitung*, 28 (1955), 180-189, reprinted in Weyl's *Ges. Abhl.*, 4, 650-654. There he also described his decision to accept the call to Göttingen as resulting from discussions, carried on in his imagination, with Jacob Burkhardt and Hermann Hesse. Weyl's wife Helene, the former disciple of Husserl, translated Ortega y Gasset into German. Planck's political conservatism is well known, but not quite so deep as it is often represented: he and von Laue were both members of the Deutsche Volkspartei in the Weimar period. (Wilhelm Westphal, “Der Mensch Max von Laue,” *Physikalische Blätter*, 16 [1960], 549-551; Friedrich Herneck, *Bahnbrecher des Atomzeitalters* [Berlin, 1969], pp. 303-304). Schrödinger's conservative nationalism is implicit in his correspondence with Wilhelm Wien, cited in note 234, most strongly in a letter of 26 April 1927 describing his emotions at the sight of the German countryside upon returning from the United States. Schrödinger frequently used Greek and Latin titles for his research notebooks (Archive for History of Quantum Physics); von Laue frequently used quotations from these languages in his publications.

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examination of other episodes of entrainment in the late nineteenth and early twentieth centuries will prove that it is also not necessary. But be that as it may, it seems difficult to deny that the shifts in scientific ideology and the anticipated shifts in scientific doctrine exposed in this paper were *in effect* adaptations to the Weimar intellectual environment. Moreover, whatever similarities one may find in the mental posture of non-German exact scientists in this same period, there is one feature which cannot, I think, be found outside the German cultural sphere: a repudiation of “causality.”