The problem of disenchantment: scientific naturalism and esoteric discourse, 1900-1939

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Physical Science in a Modern Mode

> [T]he history of physical science in the twentieth century is one of a progressive emancipation from the purely human angle of vision.
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> James Hopwood Jeans, *The New Background of Science* (1933), 5.

INTRODUCTION

The present chapter serves several interrelated purposes. It surveys central developments in the history of the physical sciences (i.e. physics and chemistry) in the period from 1900 to the beginning of World War II in order to provide a solid background reference for the rest of the book. The developments that concern us the most fall into three main streams: relativity theory, quantum mechanics, and research on radioactivity. All three fields involve distinctly new conceptual developments, achieving enormous attention and sparking much speculation *outside* of the physical sciences, addressing broader issues than strictly scientific ones. The primary motivation for providing a relatively comprehensive yet concise historical overview of these scientific developments is the recognition that much history of religion dealing with the impact of science on religious innovation tends to be rather superficial in its engagement with the history of science. Thus a number of stereotypes, projections, and emic historiographies of science have tended to be reproduced uncritically, while at other times, the lack of a critical interrogation of science itself has left many interesting research questions unanswered. Breaking this problematic trend and putting the analysis of modern science's interaction with processes of religious meaning-making on a solid historical basis, the chapter will give a nuanced picture of the problem of disenchantment in the physical sciences in the early 20th century. In combination with the following chapter, focusing on the life and mind sciences, it presents the scientific "basis" for speculative "superstructures" concerning worldviews and new natural theologies. Those superstructures shall occupy us as length in chapter six, but in order to fully assess their relation to scientific developments, and to differentiate between strategic mythmaking and actual scientific practice, it is essential to first establish a close dialogue with the history of modern science.

To illustrate the need for a closer engagement with the history of science I will begin by looking briefly at three major works in the history of religion that could all have benefitted from it. The first of these is Catherine Albanese's *Republic of Mind and Spirit* (2007), a ground-breaking work on what the author calls American "metaphysical religion". In introducing, very briefly, the emergence and importance of quantum mechanics, Albanese bases her narrative of scientific developments largely on "New Age" classics such as Gary Zukav's *The Dancing Wu-Li Masters* and Fritjof Capra's *Tao of Physics*, adding primary material from Werner Heisenberg's later popularising and speculative work.[1] The result is that we are presented with a history of science narrative that has *already* been filtered and interpreted through the lens of those who have later made rhetorical use of it. The *production* of this narrative remains unquestioned. We learn nothing about the *actual* relationship between the religious developments in question and the scientific developments they build on, make use of, or respond to, since we are only confronted with the final product. We only get to see the scientific developments through the eyes of the religious entrepreneur. Clearly, this would never be acceptable if the claims were about other parts of history (e.g. claims of tradition, hagiographies), and it should not be accepted for claims about the history of science either.

Olav Hammer's *Claiming Knowledge* illustrates a quite different problem related to the neglect of engaging with the history of modern science. Hammer's otherwise excellent analysis of the strategic uses of science by esoteric spokespersons in the modern period is built on a helpful definition of "scientism", as distinguished from actual science.[2] One problem with this definition is that it takes the thoroughly "cooked" claims of science for granted, without interrogating the process of scientific knowledge production itself. In other words, it offers a somewhat simplistic dichotomy between "proper science" and (non- or extra-scientific) "scientism", which bars the kind of questions that occupy us here.

Finally, Wouter Hanegraaff's *New Age Religion and Western Culture* opted for the methodological choice of staying away from any direct comparison with actual scientific

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[1] Albanese, *Republic of Mind and Spirit*, 397-399, 582 n. 9-10.

[2] Hammer, *Claiming Knowledge*, 206.

production when discussing works of "New Age science".[3] Thus, what I propose to call "emic historiographies of science" are taken at face value, although no claim is made that these represent scientific or historical realities. Distinctions between "holism" and "reductionism"/"materialism"/"mechanism" are identified on the emic level, and can be analysed to say something about the worldviews of the New Age spokespersons making them, and their conception of history.[4] While this is an understandable limitation from a methodological point of view, it still precludes the type of critical research questions which interest us here. Furthermore, there is a danger that distinctions found on the emic level may be subtly reproduced in etic discourse as well. For example, the reliance on terms such as 'the new scientific worldview',[5] which Hanegraaff connected to the notion of a *disenchanted* worldview, suggests such leakage, especially as long as disenchantment is connected with 'the increasing prestige of modern science and the positivist-materialist philosophies which flourished in its wake'.[6] One of the aims of this study is precisely to deconstruct this monolithic and somewhat polemical view of modern science.

Labels such as "positivist", "materialist", "reductionist", and "mechanist" do not function as clear-cut analytical concepts; they are historically imprecise and polemically loaded terms, implying certain things about the identity of "science". Using them uncritically easily reproduces polemical distinctions created in part by scientists, and in part by those wishing to argue for "re-enchantment". A major contribution of the present chapter is to look at the production of emic historiographies of the physical sciences *within* communities of scientists, and paying critical attention to the conceptual shifts and historical complexities involved. An indispensable tool for understanding this development is found in the historical thesis on the birth of quantum mechanics formulated by Paul Forman. Introducing and discussing this thesis at some length in the final parts of the chapter, I will show that it has important implications for our understanding of the problem of disenchantment, and the ways in which it was met in the natural sciences of the inter-war period. Finally, I argue that an analysis combining the Forman thesis with my revised model of disenchantment helps us reframe and

[3] Hanegraaff, *New Age Religion*, 129.

[4] E.g. ibid., 119.

[5] E.g. ibid., 462.

[6] Ibid., 421.

better understand the early development of new *esoteric* discourses. In chapter six we shall see that some of these have informed the production of new natural theologies that have since become highly influential in post-war religious and esoteric discourse. The main argument advanced in the present chapter is that they were borne from engagements with the problem of disenchantment inside of dominant scientific discourses of the early 20th century.

1 SCIENCE AND MEMORY: A HISTORIOGRAPHICAL PREAMBLE

The distinction between "classical" and "modern" physics has been a standard element in historical narratives of the physical sciences since the early 20th century. According to these narratives, the classical period was the culmination of the "scientific revolution", the outcome of the works of such men as Copernicus, Galileo, Kepler, Newton, and Descartes. More than simply a set of scientific theories and explanations of observational data, classical physics rested on a certain worldview, the "classical worldview", which was based on notions of absolute space and absolute time, and on mechanistic interactions between objects in a closed universe that was essentially deterministic. According to this conventional narrative, the classical worldview peaked at the end of the 19th century, when a new coterie of pioneers made new discoveries that ultimately would give rise to the "*modern* worldview". The heroes of this worldview were the likes of Planck, Einstein, Rutherford, Bohr, Heisenberg, Pauli and Schrödinger. In stark contrast with the classical, the modern worldview taught the relativity of space and time, and saw forces play out in a fundamentally indeterminate universe governed largely by statistical laws of chance.

The distinction between classical and modern is supposed to reflect a quite sudden and drastic conceptual switch in physics, with further implications for the "scientific worldview". While there obviously were such significant conceptual developments, as well as changes in the way scientists conceived of the implications of their theories, recent scholarship in the history of science has pointed to how dichotomies of this type have also obfuscated the nuances of how science actually developed at the *fin-de-siècle*.[7] We must not miss the fact that scientists of the "modern"

[7] The journal *Studies in History and Philosophy and Science* published a thematic issue on 'science and the changing senses of reality circa 1900' in 2008, in which several articles question common assumptions

period have made strategic use of their own history to create a narrative of revolution in which they themselves were inscribed as the avant-garde. Richard Staley has argued that 'classical and modern physics were importantly co-created, fashioned in the same period, with the former ultimately defined by the adherents of the new physics'.[8] "Classical" is a category applied retrospectively. While this may in itself be trivial, it is of more importance to emphasise that the very act of defining the old and distinguishing the "modern" was part of a strategy to break away from what was conceived as "traditional" forms of thinking about science, and hence to revise the cultural *identity* of science. There is a clear link here to the classical/modern distinction in art, literature, and music – the breaking up of established forms, the shattering of tradition, and the loss of harmony and clear vision have all been thought to characterise the modern aesthetic.[9]

The distinction between the classical and the modern in physics seems first to have taken hold following the 1911 Solvay congress in Brussels, where eighteen specially invited physicists from Germany, France, Austria, the Netherlands, Britain and Denmark met to discuss the current problems in the emerging quantum theory.[10] In his novel interpretation of the conference, Staley suggests that the most significant outcome of this conference was precisely that a new historical awareness was crafted, which would define the new generation of physicists.[11] What was at stake was the creation of a

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about the classical/modern distinction. See especially Richard Staley, 'Worldviews and Physicists' Experience of Disciplinary Change'; Richard Noakes, 'The "World of the Infinitely Little"'; cf. H. Otto Sibum, 'Introduction: Science and the Changing Senses of Reality Circa 1900'.

[8] Staley, '"Worldviews and Physicists' Experience of Disciplinary Change', 306; cf. idem, 'On the Co-creation of Classical and Modern Physics'; idem, *Einstein's Generation*.

[9] Staley, '"Worldviews and Physicists' Experience of Disciplinary Change', 299-306. For an interesting view of the overlaps between science and art in this respect, see the essays in James Elkins (ed.), *Six Stories from the End of Representation*.

[10] Staley, 'On the Co-creation of Classical and Modern Physics', 553-558; cf. idem, *Einstein's Generation*, 15, 397-421.

[11] Staley, 'On the Co-creation of Classical and Modern Physics', 554. Staley may, however, be overemphasising this point when he states that 'the congress saw no substantially new contributions to the research literature'. This seems to have become a standard phrase following Einstein's pessimistic remark after the conference that 'nothing positive came out' of it. However, the conference saw important discussions of and contributions to fields such as Brownian motion and specific heats, to which Einstein's own paper contributed. These, it must be said, represented a real conceptual break from older physics

"disciplinary memory", which gave value to "new knowledge" placed partially in contradistinction to a rearrangement and homogenisation of the old, a process that reinforced the "disciplinary identity" of what came increasingly to be seen as a new type of physics after the Great War.[12]

The above remarks are of analytical importance. First of all, they bring attention to the fact that the construction of tradition plays a role in identity formation in the sciences, as it does in other socio-cultural systems.[13] It furthermore reminds us that it is not only religious and esoteric appropriations of the sciences that are engaged in the creation of "emic historiographies of science" – we must also pay attention to the role of the scientists themselves in creating such narratives.[14] Strategic uses of the history of science are part of the rhetorical arsenal of disciplinary formation and identity-construction. Becoming aware of the retrospective creation of the classical/modern divide, we can start looking at its reception history, both within and outside of physics. Attention must be given to the new significances the distinction is invested with in light of extra-scientific agendas. This furthermore emphasises the need of a broader cultural analysis when looking at the significance attributed to certain developments that may at

research, and not only a rhetorical exercise of distancing from earlier generations. On the papers presented at the conference, see Norbert Straumann, 'On the First Solvay Congress in 1911'; cf. Galison, 'Solvay Redivivus'.

[12] The relation between the three concepts "new knowledge", "disciplinary memory", and "disciplinary identity" are central to the narrative presented in Staley, *Einstein's Generation*. See especially pp. 13-16.

[13] For "the invention of tradition" as a critical concept in historiographical research, see Eric Hobsbawm & Terence Ranger (eds.), *Invention of Tradition*. Cf. the classic study by Shils, *Tradition*.

[14] On the distinction between emic and etic historiography, see Hammer, *Claiming Knowledge*, 85-89: 'Following the common usage of the terms *emic* and *etic* in anthropological literature to distinguish the informants' views from those of the researchers, secular studies can be described as etic, whereas the accounts of believers constitute emic historiography' (ibid., 86). Whereas the secular/believer distinction is problematic and does not work properly in this context, the division between insider and outsider accounts still remains. Etic historiography might more conveniently be given the pragmatic definition of the historiography which is written by professional historians in any given field, and which would, at any given time, resonate with the views accepted in peer reviewed journals in that field. By contrast, emic historiographies are meaningful in light of discourse-internal assumptions, but are not necessarily corroborated by up-to-date academic historiography. Note how this definition resonates with my naturalistic constructionism laid out in chapter three, a position which rests on a pragmatic, "endoxic" appeal to what our best current scholarship has to say on any given matter.

first seem purely "internal" to science. A certain discovery is not revolutionary in and of itself; it has to be recognised as such by someone for a reason. These reasons may at least in part lie outside of "pure science", and hence call for a mild sort of "externalism" about scientific development.

The precise role of extra-scientific influences on scientific developments in the early 20th century, and the construction of "revolutionary" science, has sparked much debate in the historical literature. Later in this chapter I will discuss one such perspective at some length, namely the Forman thesis on the development of quantum mechanics.[15] Before getting to that, however, we need to have a more straight-forward factual overview of central scientific developments of the period. I will focus on three major developments which would go on to have a deep intellectual impact beyond scientific communities: the relativity theories, quantum mechanics, and the science of radioactivity.

2 Relativities: A Straight Story

Relativities I: The Special Theory, and Some Precursors

The relativity theories in physics are primarily associated with the iconic figure of Albert Einstein (1879–1955). In the conventional story, Einstein's 1905 paper 'On the Electrodynamics of Moving Bodies' introduced the special theory of relativity (STR). The general theory (GTR) completed the relativistic programme in physics ten years later, when it was presented as a paper before the Berlin Academy of Sciences in November 1915.[16] Together these papers sparked a revolution in physics and cosmology, giving rise to a fresh view of the world and a new way of perceiving physical phenomena.

[15] E.g. Forman, 'Weimar culture, causality, and quantum theory'; idem, 'Reception of an Acausal Quantum Mechanics in Germany and Britain'; idem, '*Kausalität*, *Anschaulichkeit*, and *Individualität*, or How Cultural Values Prescribed the Character and Lessons Ascribed to Quantum Mechanics'; Stephen Brush, 'The Chimerical Cat'; John Hendry, 'Weimar Culture and Quantum Causality'; J. L. Heilbron, 'Earliest Missionaries of the Copenhagen Spirit'; Helge Kragh, *Quantum Generations*, 151-154.

[16] The original 1905 paper was entitled 'Zur Elektrodynamik bewegter Körper' and published in *Annalen der Physik.* All the central papers on SPR and GTR are collected with explanation and introduction in Lorentz, Einstein, Minkowski, and Weyl, *The Principle of Relativity* (originally published in 1923). There has been a long priority dispute regarding both STR and GTR, some aspects of which will be addressed below. For a useful and constructive comparison between the early relativity theories of Einstein and

However, emphasising the place of Einstein means obscuring the gradual development of the ideas from which the relativity theories emerged. Some of the main lines of inquiry could at least be stretched back to 19th century optics' interest in the relative motions of the speed of light, moving bodies, and a stationary ether. The famous Michelson-Morley experiment, first conducted in 1887, is a particularly obvious case in point, especially since it was later conscripted as evidence for relativity.[17] The popular view that the Michaelson-Morley experiment was the end of ether physics, ushering in the age of relativity, is, however, erroneous and a good example of a strategic reinterpretation of earlier physics to serve presentist goals.[18] The experiment had originally been designed to distinguish between different *types* of ether theories, and its famous null-result, although puzzling and unexpected, was still capable of being incorporated into the conceptual framework of 19th century ether theory.[19]

Despite appearing less "revolutionary" when viewed in the context of its historical precursors, it is undeniable that Einstein's 1905 paper had several unique and innovative aspects to it. While he did know about the Michelson-Morley experiments and concurrent debates, he did not make an explicit connection between these and his

Poincaré, see Peter Galison, *Einstein's Clocks, Poincaré's Maps*. An authoritative historical account of Einstein's development of SPR can be found in John Stachel, ' "What Song the Syrens Sang": How Did Einstein Discover Special Relativity?'. For the GTR, see Stachel, 'How Einstein Discovered General Relativity'. For the relation of relativity to earlier (and competing) notions of time and space, cf. J. B. Kennedy, *Space, Time, and Einstein*. A concise but meticulous historical overview is available in Kragh, *Quantum Generations*, 87-104.

[17] The relation between relativity theory and the Michelson-Morley experiment with its many variations and repetitions up until the 1930s is discussed in great detail in Lloyd S. Swenson, *The Ethereal Aether*.

[18] See ibid., 188-189.

[19] The experiment was set up by American physicists Albert Michelson (1852–1931) and Edward W. Morley (1838–1923), and looked for speed differences between beams of light moving in opposing directions relative to the earth's movement. This made it possible to test a prediction of the stationary ether model, championed by August-Jean Fresnel, which predicted an "ether wind" effect influencing measurements of the speed of light made on bodies moving through the ether (e.g., the Earth itself). The main competitor to this model was George Gabriel Stokes's movable ether, which hypothesised that heavy objects would drag the ether with it. Instead of "disproving" the ether, the null result of the Michaelson-Morley was consistent with Stokes's hypothesis of an "ether drag" effect: the speed of light would appear uniform on a moving earth, because the planet dragged the ether with it. For a discussion of these theories and the relation to the experiments, see Edmund Taylor Whittaker, *A History of the Theories of Aether and Electricity*, 137-87, 411-7; cf. Swenson, *The Ethereal Aether*, 3-31.

principle of special relativity, which did, however, explain the experiment's null-result. The manner through which Einstein developed his theory is in itself striking: it relied heavily on thought-experiments rather than actually performed experiments, and was radically deductive in character. It started by reflecting on certain "asymmetries" arising from Maxwellian electrodynamics, before proposing two postulates that would give a simple and coherent account of the electrodynamics of moving bodies. The two famous postulates were 1) *the principle of relativity*, stating that the laws of electrodynamics and optics are the same for all inertial frames of reference, while abolishing the notion of a privileged, absolute frame of reference; and 2) that *light in empty space travels at a constant velocity* independent of the state of motion of the body emitting it.[20] From these two postulates Einstein was able to derive a number of strange and counterintuitive notions, such as length contraction, time dilation, and the relativity of simultaneity.

Again, these effects and postulates were not entirely new. The French mathematician and physicist Henri Poincaré had postulated the constant velocity of light already in 1898, developed a notion of relativity of observation to inertial frames in 1904, and published a mathematical exposition and restating of his relativity principle as a general law of nature in the summer of 1905, just a few months before Einstein's paper was published.[21] Indeed, Poincaré seems to have considered Einstein's special theory rather trivial.[22] In 1889 George FitzGerald had been the first to introduce a hypothesis of length contraction, in what was at the time a completely speculative and rather *ad hoc* explanation of the Michelson-Morley experiment.[23] A contraction effect was similarly postulated by Lorentz, who also worked out the mathematics of it. But whereas Lorentz and FitzGerald had been working to solve an experimental puzzle which did not make sense according to present theories, Einstein came to the same conclusions through a radically deductive approach from the two postulates introduced in the beginning of his paper. Furthermore, Einstein's conclusions concerned *measurement* rather than the real properties of objects. Since Lorentz and FitzGerald operated with a notion of absolute time and space, defined in relation to a stationary

[20] Einstein, 'On the Electrodynamics of Moving Bodies', 37-38.

[21] Kragh, *Quantum Generations*, 89-90.

[22] Goldberg, 'In Defense of Ether', 96-97. Cf. Kragh, *Quantum Generations*, 87-90.

[23] An account of FitzGerald's proposal and its reception is given in Hunt, *The Maxwellians*, 192-197.

and uniform ether, contraction for them had to be understood as a change in the real physical properties of bodies in motion: moving bodies really did become shorter.[24] In Einstein's STR the phenomenon is explained rather as a product of measurements conducted in states of *relative* motion. By applying the same logic to measurements of time, an effect of "time dilation" was predicted: measurements of time vary between different reference frames moving at different velocities relative to each other. This, in turn, gave rise to the counterintuitive notion that *simultaneity* is relative: two spatially separate events cannot be *absolutely* simultaneous. Instead, the sequence of two events will vary based on the reference frame of the observer.[25]

In one sense, STR reinterpreted certain known effects by abolishing reference to an ether and the notions of absolute time and space that had been attached to it. However, it is another myth in the history of relativity theory that it expelled the old ether physics immediately. Special relativity did not *disprove* the ether; rather, it followed the principle of parsimony by stating that 'the introduction of a "luminiferous ether" will prove to be superfluous'.[26] Furthermore, the immediate reception of STR differed from country to country, and its implications for the ether theory were conceived differently in various national contexts.[27] During the period from 1905 to 1911 various commentators would contest, elaborate, and defend Einstein's theory.[28] Germany was the first place where Einstein was thoroughly discussed and actually understood, as one would expect since he published in German journals. The situation was completely different in France, where Poincaré dominated the physics community. Here Einstein was hardly ever mentioned prior to his visit to the country in 1910. Meanwhile in the United States, the tendency was to ridicule what American physicists found to be an absurd theory with impractical or even contradictory conclusions.[29] This conception was due in no small part from a general lack of interest and ignorance of the exact content and implications of the theory, but also due to a basic conviction that

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[24] Both speculated about changes in molecular forces, without being able to pinpoint any exact mechanism. See Kragh, *Quantum Generations*, 88.

[25] An accessible discussion of these concepts and their interpretations is available in Kennedy, *Space, Time, and Einstein*.

[26] Einstein, 'On the Electrodynamics of Moving Bodies', 38.

[27] See especially Goldberg, 'In Defense of Ether'; cf. Swanson, *The Ethereal Aether*, 171-189.

[28] Goldberg, 'In Defense of Ether', 97-98.

[29] Ibid., 98.

physics ought to express its theories in completely intuitive categories. The Americans' attitude was largely shared by the British science community, where physicists were trained to think with the concept of ether in a much more systematic way than anywhere else.

To the extent that special relativity revolutionised physics, it was a slow revolution. It arose from earlier research programmes, and it was not immediately accepted. This gives us reason to be suspicious of exaggerated claims of a revolution occurring around 1905; that is a claim which belongs to the realm of emic historiographies. In reality, relativity was born from research programmes in Victorian physics, especially Maxwellian electrodynamics and ether physics. The "modern" gradually grew out of the "classical".

RELATIVITIES II: THE GENERAL THEORY AND THE BIRTH OF MODERN COSMOLOGY

Einstein's general theory of relativity (GTR) was developed gradually through a series of papers between 1907 and 1915. It was essentially a new theory of gravitation, resting on a generalisation of the insights from STR, and a novel geometrisation of space and time. In short, the theory attempted to give a new description of Newton's law of universal gravitation, an effect which had essentially lacked a mechanism for over 200 years. GTR contributed a new description of gravitation as a *geometrical* property of space and time, or more precisely, of the curvature of the spacetime continuum.

As with the STR, the GTR had first been conceived from a number of innovative thought-experiments regarding motion, acceleration, and weight. It started with the so-called "equivalence principle", first stated in 1907, which postulated that there is no difference between the "force" experienced by the gravitational pull of heavy object (such as the Earth) and an equal force felt while standing in an accelerating reference frame (e.g. inside a rocket).[30] However, its full formulation required the development of a set of highly complex equations, known as the "Einstein field equations", which essentially make up the hard core of the theory. These equations were presented before the Berlin Academy of Sciences in November 1915.

Several explanations and predictions could be derived from these equations, a fact which was crucial for the persuasiveness and eventual acceptance of the theory.

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[30] Einstein, 'On the Relativity Principle and the Conclusions Drawn from It'.

The theory provided a satisfying explanation of the anomaly of the precession of Mercury's perihelion; but much more spectacularly, it predicted that light could be bended around heavy objects due to the curvature of space.[31] While Mercury's eccentric perihelion was a well known phenomenon, the precise description of how light would bend around heavy objects constituted a completely novel empirical prediction. An opportunity to test the hypothesis arose only a few years after the prediction was made, during the solar eclipse of 1919. British physicists arranged two expeditions to areas where the eclipse was total: Frank Dyson went to Principe Island, off the western coast of Africa, while Arthur Eddington headed to Sobral in Brazil. Observing and photographing the event, the physicists were able to conclude that stars passing by the blackened sun did indeed seem to change their positions to a degree that was in good (although not perfect) agreement with Einstein's prediction.[32]

Due to its wide range of consequences for astrophysics and its new topographical approach to the universe, the acceptance of general relativity was a significant impulse for the birth of modern cosmology. Einstein himself may be seen as initiating this movement with his paper on 'Cosmological Considerations Concerning the General Theory of Relativity', published in the *Proceedings of the Prussian Academy of Sciences* in 1917.[33] Other notable scientific cosmologists include Eddington and James Jeans (both of whom will be discussed in much more detail in our later chapter on natural theology), as well as the Dutch physicist Willem de Sitter, the Belgian Georges Lemaître and the American astronomer Edwin Hubble. In the period between 1917 and 1930, the main problem cosmologists were occupied with was whether the universe was closed or open, with Einstein's model supporting a closed variety. When Hubble found observational evidence for the expansion of the universe in 1930, the field moved

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[31] A third prediction was the phenomenon of "gravitational redshift", meaning a change in the observed wavelength of electromagnetic radiation due to the relative strength of the gravitational fields of the emitting and the receiving body. This effect was very difficult to measure, and did not form a persuasive part of the case for GTR until the late 1950s.

[32] See Kragh, *Quantum Generations*, 97.

[33] Ibid., 349.

on to be more interested in determining origins and ends, with the "big bang" model emerging as a leading hypothesis.[34]

However, the GTR's account of gravitation also had other implications for cosmology. It gave a new framework for explaining the evolution of stars and solar systems, and the formation of gravitational singularities, or black holes. All of these have continued to be central areas of research for scientists interested in the size, shape, history, and destiny of the cosmos as a whole, and have greatly contributed to an understanding that the universe is an even stranger place than it seems from a pleasant, blue earth.

3 The Development of Quantum Physics

A Chronological Overview

The field of quantum physics developed parallel to the relativity theories, focusing on the study of certain newly discovered subatomic particles and the interactions of matter and electromagnetic phenomena. In the present section I will provide a brief and essential chronology of how the quantum theory developed into a system of quantum mechanics between approximately 1900 and 1930. This overview will be based on a standard "internalist" narrative, with a couple of important contextualising points where they seem particularly relevant for the overall argument.[35] With an overview of the basic historical facts in place, we shall later turn to a thorough discussion of an "externalist" interpretation of the early history of quantum mechanics associated with the Forman thesis.

Quantum theory developed out of two lines of research arising in the early 1900s, namely Max Planck's research on black-body radiation, and Einstein's 1905 work on the

[34] The first variety of a big bang model of the origin of the universe had been proposed, although rather speculatively at the time, by Lemaître in 1927. It was largely ignored until Hubble's significant discovery. See Kragh, *Quantum Generations*, 349-350.

[35] The basic factual claims about historical sequence in this section have been borrowed from Helge Kragh, *Quantum Generations*, which is a meticulously documented standard work in the history of 20th century physics, building on, commenting, and synthesising decades of earlier scholarship in this field. I have, however, also referenced a number of other sources to supplement Kragh on particular issues. All of this is indicated in the footnotes, supplied with precise references to primary sources when deemed particularly important.

photoelectric effect. While Planck's research showed that thermal radiation from black-bodies deviated radically from what was expected by "classical" models in thermodynamics, Einstein's signalled the fall of the wave theory of light by proposing that electromagnetic radiation was to be understood as localised quanta of energy, which would later be termed "photons". The importance of these developments were recognised during and following the 1911 Solvay conference, where, as we have seen, the idea of a break away from a "classical" worldview was taking shape. Following the Solvay congress, new models of the atom were developed on the lines of the emerging quantum theory and atomic physics: Ernest Rutherford first presented his important but entirely "classical" planetary model of the atom in 1911 (more on this in the next section), and Niels Bohr enhanced it in 1913 by bringing it up to speed with the new quantum theory. At this point, a coherent non-classical picture of the nature of matter was starting to take shape, growing out of the Solvay conference community.[36]

The international cooperation that had just started bearing fruits was halted by the outbreak of war in 1914. Physicists were suddenly not just physicists: 'they were now German physicists, French physicists, Austrian physicists, or British physicists'.[37] Cooperation was exchanged for chauvinism, and the efforts of European scientists were increasingly directed away from fundamental physics towards the development of industrial and military applications.[38] In Germany, physicists now helped develop poisonous gases and telecommunication technologies for military and espionage purposes. Across the channel, English physicists worked on new ranging techniques for use with antiaircraft systems and for detecting the much feared German submarines.[39] Some "pure physics" was still carried out despite this militarisation of scientific production, but the international cooperation that had characterised development of the earlier quantum theory ceased. When collaborative work on quantum physics re-emerged after the war it was in a very different cultural climate, torn by the destructive power of new weaponry, and characterised by growing social, political and economic anxieties.

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[36] Again, compare this view with Staley's cited above.

[37] Kragh, *Quantum Generations*, 131.

[38] Hartcup, *The War of Invention*; cf. Jeff Hughes, *The Manhattan Project*, 15-44; Kragh, *Quantum Generations*, 120-135.

[39] Overview in Kragh, *Quantum Generations*, 133-134.

International cooperation was slowly restored after the war. Above all, Niels Bohr succeeded in building an institution in Copenhagen in the 1920s that facilitated and benefited from a unique spirit of exploration in an environment of international cooperation, a milieu that would give rise to the dominant "Copenhagen interpretation" of quantum mechanics.[40] Bridging some of the national divides that had widened as a consequence of war, Bohr's institute attracted as many as 63 visiting physicists from 17 countries between 1920 and 1930.[41] Copenhagen became the central connecting point on what may be termed the Copenhagen-Munich-Göttingen axis – three extremely productive milieus in the production of quantum mechanics in the 1920s.

A series of essential breakthroughs occurred in the period 1924–1927, leading to the development of a number of important concepts. In 1924, the French physicists Louis De Broglie proposed a model of wave/particle duality, which would go on to inspire new interpretations, especially in the work of Erwin Schrödinger.[42] Another event of 1924 was connected with the collaboration of Bohr, the Dutch physicist Hendrik Kramers, and the American John Slater. Together, they developed a controversial theory that radiation phenomena could not be given a causal explanation, arguing that the interaction between atoms and radiation only allowed for statistical descriptions.[43] Although the original Bohr-Kramers-Slater theory proved to be inconsistent with experiments, its rejection of causality for certain phenomena would greatly influence later developments in quantum mechanics.

1925 brought new important developments. Wolfgang Pauli published his exclusion principle, which clarified some unsolved issues in Bohr's atomic model, and Heisenberg developed the first relatively successful attempt to create a full mechanical theory for quantum mechanics: the highly abstract and mathematical "matrix mechanics". The idea was first suggested by Heisenberg alone, arguing for a purely abstract and mathematical redefinition of mechanics, but it was only completed through collaboration with Heisenberg's senior colleague in Göttingen, Max Born, and Born's

[40] See especially Peter Robertson, *The Early Years: The Niels Bohr Institute, 1921–1930*.

[41] See table 11.1 in Kragh, *Quantum Generations*, 160; cf. Robertson, *The Early Years*.

[42] Kragh, *Quantum Generations*, 164.

[43] Ibid., 161.

assistant, the young Pascual Jordan.[44] The new matrix mechanics was impractical, however, and it was met with much scepticism due to its unusual and difficult mathematical formalism.

In the following year, 1926, the Heisenberg-Born-Jordan matrix mechanics was challenged by the Austrian physicist Erwin Schrödinger.[45] Matrix mechanics was essentially a *particle* model of energy quanta; Schrödinger, picking up on the still little known work of De Broglie, developed a new *wave model* that was able to account for the same data. An advantage of Schrödinger's model was that it could be expressed in a formalism that was well-known, while satisfying the conceptual preference for continuity in nature.[46] Thus arose the unusual situation that two mechanical models that assumed very different fundamental views of nature and deployed different mathematical tools appeared explanatorily equivalent. Schrödinger demonstrated that his wave function could be translated into corresponding expressions in matrix mechanics, and the other way around.[47] The same year, Born suggested a *probability* interpretation, which combined the wave function with the particle model by considering the function as an expression of the probabilities of the whereabouts of an electron. This apparently solved the problem, but only by introducing an irreducible probabilistic element into physics; nevertheless, it soon won popularity in the Copenhagen-Göttingen-Munich axis.[48]

An intense period of scientific developments was concluded in 1927, when Heisenberg published his "uncertainty principle" and Bohr developed the concept of "complementarity". Both concepts touched explicitly on philosophical aspects of quantum mechanics, and both became defining elements of the Copenhagen interpretation.[49] Heisenberg's principle was initially derived by way of a philosophical reflection on an experimental problem, strongly influenced by an anti-metaphysical

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[44] Heisenberg's original paper was published in *Zeitschrift für Physik* in september 1925, and the so-called "Dreimännerarbeit" appeared a few months later, in November. Cf. Kragh, *Quantum Generations*, 162-163.

[45] Ibid., 163-165.

[46] Ibid., 165-166.

[47] This was strengthened further the same year by Jordan and Paul Dirac, who independently of each other developed a transformation theory unifying Heisenberg and Schrödinger's models. Cf. ibid., 166.

[48] Ibid., 166-167.

[49] See Brush, 'The Chimerical Cat', 396; Heilbron, 'Earliest Missionaries of the Copenhagen Spirit'.

instrumentalist version of positivism.[50] Heisenberg's starting point was that statements about "the position of an electron" were only meaningful when defined in terms of the *experimental procedures* through which position may be measured. In quantum mechanics this was problematic, because the experimental procedure for determining an electron's position involved manipulating that entity so that its *momentum* would change. Thus it was impossible even in theory to precisely determine both the position and the momentum of particles at the same time. Measuring one value meant manipulating the other. Heisenberg thus proceeded to give the next-best option: deriving an equation expressing the minimum necessary degree of indeterminacy in measurements of position and momentum.

This might at first appear to be a mere practical inconvenience in the study of subatomic particles. Heisenberg, however, saw much deeper philosophical consequences in his argument. The uncertainty principle, according to Heisenberg, demonstrated that physics can never know all aspects of a given physical system, since some observations mutually exclude one another. Furthermore, if the present state of a physical system cannot be determined, then it follows that we cannot determine the future state of any system either. In this way Heisenberg's argument acts as a counterpoint to Laplace's famous thought experiment about the calculability of all future events: classical causality, and particularly classical determinism, falls. One might still object that, even if this epistemological point holds true (that physicists' possible *knowledge of* nature is limited), nature may still be causally determined on some deeper level to which we do not have access. However, since Heisenberg's point was a radically positivistic one, he countered that any such claim was pure speculative metaphysics devoid of meaning:

> As the statistical character of quantum theory is so closely linked to the inexactness of all perceptions, one might be led to the presumption that behind the perceived statistical world there still hides a "real" world in which causality holds. But such speculations seem to us, to say it explicitly, fruitless and senseless. Physics ought to describe only the correlation of

[50] The paper was published in the journal *Zeitschrift für Physik* as 'Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik'. An English translation is available as 'The Physical Content of Quantum Kinematics and Mechanics', in John Archibald Wheeler & Wojchiech Hubert Zurek (eds., trans.), *Quantum Theory and Measurement*, 62-84. For discussions, see Jammer, *The Philosophy of Quantum Mechanics*, 56-71, 75-78; cf. Peter Dear, *The Intelligibility of Nature*, 151-156.

> observations. One can express the true state of affairs better in this way: Because all experiments are subject to laws of quantum mechanics … it follows that quantum mechanics establishes the final failure of causality.[51]

Already before the paper was published, Bohr had commented to Heisenberg that his thought experiment on the problem with measuring electrons had a weakness in that it rested too much on a classical particle picture, while neglecting the wave aspects of photons and electrons.[52] It was this problem that Bohr tried to capture in his own concept of *complementarity*, which was first presented at a 1927 conference in Como, Italy, commemorating the centennial of Alessandro Volta's death.[53] Following Heisenberg's point about the indeterminacy of measurement, Bohr stressed that one cannot measure the state of a quantum mechanical system without disturbing it. The implication of this, in Bohr's view, was that a strict distinction between the observer and the observed was not anymore tenable. This seemed to pose serious problems for the possibility of truly objective knowledge in physics. The complementarity principle was a way to phrase this problem, but also an attempt to overcome its worst consequences. It followed from Heisenberg's principle that the observer, in setting up the experimental apparatus, must decide whether to measure the momentum or the position of a quantum entity. Quantum mechanics thus permit *complementary* descriptions of physical systems, Bohr argued, meaning descriptions which are mutually exclusive, but equally necessary for a complete picture to be formed. Bohr's most central example was the wave/particle duality: some experiments require light to behave according to a wave model, while other experiments only make sense when a particle model is assumed.[54] This apparently fragmented and contradictory picture of the world did not trouble Bohr, in large part due to the conspicuous anti-realistic positivism that characterised the Copenhagen school. 'In our descriptions of nature', Bohr claimed, 'the purpose is not to disclose the real essence of the phenomena, but only to track down, as

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[51] Heisenberg, 'The Physical Content of Quantum Kinematics and Mechanics', 83.

[52] Dear, *The Intelligibility of Nature*, 156-157.

[53] Bohr, 'The Quantum Postulate and the recent Development of Atomic Theory'; cf. Heilbron, 'Earlies Missionaries of the Copenhagen Spirit'; Kragh, *Quantum Generations*, 209-212; Dear, *The Intelligibility of Nature*, 156-158.

[54] Heilbron, 'Earliest Missionaries of the Copenhagen Spirit', 197-198.

far as it is possible, the relations between the manifold aspects of our experience'.[55] Science is not concerned with external reality "in itself", but merely with the systematisation of experience.

Debates about the completeness of quantum mechanics continued with increased force in the 1930s. The stage for this conflict was set during the fifth Solvay conference in 1927, in which Bohr presented his complementarity principle and defended the view that the Bohr-Heisenberg version of quantum mechanics was a complete theory, while Einstein devised various thought experiments aimed to show how quantum mechanics had to be incomplete (and, moreover, incompatible with his own theories).[56] Although the general verdict was that Bohr had emerged victorious, Einstein would continue to challenge quantum mechanics in the decades that followed.[57] By the 1930s, the debate focused particularly on the notion of indeterminacy and causality, and the possibility of a competing interpretation based on "hidden variables". The supporters of hidden variables experienced a heavy blow in 1932 when mathematician John von Neumann published what he claimed to be a mathematical proof showing that no such interpretation was possible. Von Neumann's proof played almost exclusively a *rhetorical* role in establishing the Copenhagen interpretation's hegemony: of those who referenced it, almost no-one had read it, at least not very carefully. In fact, when new interest in hidden variables emerged in the 1950s von Neumann's work was thoroughly scrutinised by mathematical physicists, resulting in the discovery of several inconsistencies and gaps in the argument.[58]

Two final attacks on the Copenhagen hegemony which should be mentioned came in 1935, once again in the form of thought experiments: the "Einstein-Podolski-Rosen (EPR) paradox", created by Einstein together with his Princeton colleagues Boris Podolski and Nathan Rosen; and Schrödinger's famous cat experiment. The purpose of both was to give a kind of *reductio ad absurdum* argument, showing that quantum mechanics in its present form leads to absurdities and must therefore be incomplete.

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[55] Quoted in ibid., 219.

[56] For documentation, see especially Andrew Whitaker, *Bohr, Einstein, and the Quantum Dilemma*.

[57] Kragh, *Quantum Generations*, 213-215.

[58] Ibid., 245. Note, however, that John Bell, who discovered these inconsistencies, would become more famous for his Bell theorem, which is another "no-go" theorem excluding *local* hidden variables as physically impossible. Cf. Arthur Fine, *The Shaky Game*, 40-63, 151-172.

Both may be seen as “realist” attacks on the consequences of the largely anti-realist or instrumentalist theory. EPR attempted to show that if one understands physical *concepts* as corresponding to physical *realities*, then one is left with inconsistencies that only have two possible resolutions: either one must break the “speed limit” of light required by special relativity, or one must assume a hidden variables model.[59] Less technical in form, Schrödinger’s paradox involved the fate of an unfortunate cat put in a box that would be filled with cyanide acid once a radioactive substance made its first emission. Since the decay of radioactive materials is an indeterminate process, there is no way of knowing whether the cat is alive or dead at any given time. Since the Copenhagen interpretation assumes that there is no “reality” to the issue until a measurement is made, one is left with the paradoxical position that the poor cat is lost in an unreal limbo of both dead and alive at the same time. Despite the impression one sometimes gets from popular accounts from the 1970s onwards, Schrödinger intended this thought experiment to demonstrate what he found to be a blatant absurdity inherent to the anti-realist dogma of the Copenhagen school.

The EPR and Schrodinger’s cat have become famous in philosophical and popular expositions of quantum mechanics, but they did not engage a large audience in the 1930s. The Copenhagen hegemony had been established, and the majority of physicists had better things to do than engage in what seemed rather futile and unnecessary philosophical discussions of a model that worked perfectly fine in practice.

4 RADIOACTIVITY: THE NEWER ALCHEMY?

We now turn to a third scientific development that has been of great importance not only to modern science and technology, but to the broader cultural perception of science as well: the discovery of radioactivity. As experimental studies of this strange form of energy started to emerge around the turn of the century by the likes of Marie and Pierre Curie, Ernest Rutherford, and Frederick Soddy, it became increasingly clear

[59] There is some disagreement and controversy over the exact interpretation of the EPR paradox. As Arthur Fine has pointed out, Einstein and Podolski seems to have wanted different things with it, and it was the latter who typed up the article that was published in 1935. All versions, however, clearly target the Copenhagen interpretation of quantum mechanics as being absurd, contradictory, or incomplete. See Fine, *The Shaky Game*, 26-39.

that the phenomenon shed important light on the nature of matter. Radioactivity would cause a revolution in chemistry, which had long rested on the philosophical view that the atoms of the elements were unbreakable, stable, and eternal entities. This had notably been the view of John Dalton's (1766–1844) atomic theory, and it was at the foundation of Dmitrii Ivanovich Mendeleev's (1834–1907) periodic table of the elements. It had been an extremely successful hypothesis, leading to much fruitful research and the ushering in of a veritable "golden age" of chemistry in the 19th century.[60] Due to such successes, the Daltonian view of stable, unbreakable atoms, governed by predictable mechanical interactions, had also become a standard ingredient in conceptions of the "scientific worldview": it was one of the pillars of Victorian scientific naturalism and an important component of the kind of "disenchanted world" implied by Laplace's thought-experiment of an omniscient "demon" capable of calculating all events in the universe. To the frustration of an earlier generation of chemists, those who studied radioactivity were starting to suggest that the Daltonian picture was fundamentally wrong. Radioactivity suggested that material atoms were themselves composite and unstable, and that elements might even be capable of *transmuting* from one into another.

It smacked of alchemy. In fact, in what might first look like a surprising re-evaluation of chemistry's ultimate "negative Other", references to alchemy soon became a standard trope for addressing radioactivity and the related discourse on the transmutation of metals. It was embraced by some of the leading scientists working in the field: chemists and physicists such as Frederick Soddy (1877–1959), William Ramsay (1852–1916), and Ernest Rutherford (1871–1937) were all explicit about the relation to alchemy. By the 1930s, when the theoretical revolution of radioactivity was settling down and technical applications were beginning to see the light of day, even standard textbooks would emphasise the link. Examples include Dorothy Fisk's *Modern Alchemy* (1936) and Rutherford's *The Newer Alchemy* (1937), both of which were favourably reviewed in the *Journal of Physical Chemistry*.[61] The reviewer of Rutherford's book even exclaimed that no-one was better qualified to write a comparison of the 'ancient' and 'modern alchemy' than the man 'who observed the first transmutation by

[60] On this period in chemistry, see e.g. Mary Jo Nye, *Before Big Science*, 1-56.

[61] C. S. Lind, 'Review of Dorothy Fisk, Modern Alchemy'; idem. 'Review of Ernest Rutherford, The Newer Alchemy'.

bombarding nitrogen with alpha particles and in whose laboratory … the first transmutation by purely artificial means' had been achieved.[62] Radioactivity had given alchemy a new place in the scientific imagination of the early decades of the 20th century.

The development of a "modern alchemy" on the intersection of chemistry, physics, radioactivity, historiography, popularisations of science, and even practical occultism, has recently been documented by Mark Morrisson, and it will be superfluous to reproduce his findings here.[63] Instead, we will focus on two points that are of immediate importance for our present concerns. First, the reinterpretation of alchemy in the early 20th century must be related to the broader shift in historiographical awareness that we see in this period. In short, what is the role of modern alchemy in view of emic historiographies of science? Secondly, and more importantly, the scientific *and* discursive developments of radioactivity must be placed in the context of our ongoing discussion of disenchantment. What did the "modern alchemy" mean for the problem of disenchantment? To what extent did radioactivity, a field of inquiry which posterity has tended to link automatically with the greatest destructive powers created by man, the most inhumane face of technological mastery, represent in its early years yet another contestation of the supposedly disenchanted worldview of "classical" science? I will return to these questions later, but first we must gain a basic overview of the scientific developments involved.

THE DISCOVERY OF RADIOACTIVITY, PHASE 1: BECQUEREL AND THE CURIES

In 1896, Henri Becquerel (1852–1908) had found that uranium salts spontaneously emitted a mysterious form of energy, which clouded nearby photographic plates with black spots.[64] While it was first thought to be a form of x-ray phenomenon, its deviation from the expected pattern soon suggested otherwise and the phenomenon was labelled "uranium rays". Two years later, in 1898, Pierre (1859–1906) and Marie Curie (1867–1934) discovered two new elements, polonium and radium, while examining uranium ore in their laboratory in Paris. Both elements emitted an extremely intense energy, which behaved like Becquerel's uranium rays. Since this energetic ray now seemed

[62] Lind, 'Review of Ernest Rutherford, The Newer Alchemy', 693.

[63] Morrisson, *Modern Alchemy*.

[64] Gordin, *A Well-Ordered Thing*, 211-212. Cf. Kragh, *Quantum Generations*, 30-32.

connected not only with the element uranium, Marie Curie coined the more general term "radioactivity". By the early 1900s it had become clear that radioactive emissions were of a complex nature: they appeared to be a mix of several types of radiation, which became known as alpha, beta, and gamma rays.[65] While the beta and gamma rays were quickly identified as "electromagnetic" phenomena (beta rays were later shown to be electrons emitted from the atom, while gamma rays are extremely energetic, high frequency electromagnetic waves), the nature of the alpha rays was more controversial.[66]The leading hypothesis proved particularly controversial for chemists, because it contradicted the established view of stable, immutable elements: it held that radioactivity involved the *decay* of the radioactive elements, gradually transmuting into other, lighter elements in the process.

The Russian chemist Mendeleev, originator of the vastly important periodic law, was one of the staunchest opponents of this interpretation of radioactivity.[67] His worry was that, in opening up for the spontaneous decay of chemical elements, Curie's theory of radioactivity introduced an unwanted *capriciousness* to the understanding of matter. In a personal notebook from his visit to the Curies' laboratory in Paris in 1902, Mendeleev even likened their work to spiritualism – a phenomenon he had spent many hours debunking in Russia: 'must one admit that there is spirit in matter and forces? Radio-active substances, spiritualism?'[68] In attempts to save the old metaphysics of chemistry, Mendeleev proposed alternative theories to account for the radioactive phenomena. Dismissing the emerging ideas as an attack on chemistry itself by a

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[65] See Kragh, *Quantum Generations*, 32-33.

[66] For a tidy chronological overview of these debates and the experiments involved, between 1898 and 1902, see Thaddeus J. Trenn, *The Self-Splitting Atom*, 10-14.

[67] On Mendeleev, see Gordin, *A Well-Ordered Thing*.

[68] Mendeleev quoted in Gordin, *A Well-Ordered Thing*, 213. I have not been able to double-check this quotation, which is taken from an unpublished notebook. Besides Gordin's work, it is only discussed in the Russian secondary literature. While the comparison with spiritualism is no doubt a rhetorical exaggeration on the part of Mendeleev, it is not hard to imagine why he would seize on it: Mendeleev was known as a fierce critic of spiritualism in Russia, having spent some time debunking it; the Curies, on the other hand, (and especially Pierre) were dabbling in spiritualist séances, and also partook in "scientific investigations" of famous mediums in Paris. For these reasons, it was perhaps easy for Mendeleev to draw this particular connection in order to express his worries about the view of animated matter that radioactivity seemed to suggest. It appears that both spiritualism and radioactivity were topics on which Mendeleev and the Curies disagreed.

combination of 'superstition and sloppy reasoning', he even took to ether theory in order to find a physical hypothesis for radioactivity that did not violate the immutability of atoms.[69]

Radioactivity, Phase 2: Soddy, Rutherford, and the Transmutation of Elements

The disintegration and transmutation theory was to win general acceptance in what may be termed the second phase of radioactivity research, from 1903 to 1919. This period is demarcated by the year that natural, spontaneous transmutation was first observed in a laboratory (1903), and the year when controlled, *artificial* transmutation was achieved (1919). Central to this development were the New Zealand-born physicist Ernest Rutherford, and the young English chemist Frederick Soddy. Between October 1901 and April 1903 the two cooperated on what would become highly influential work at McGill University in Montreal, Canada, establishing the transmutation theory experimentally, and sparking off a quest for artificial transmutation.[70]

Rutherford and Soddy experimented with the radioactive element thorium, demonstrating that the radioactive alpha-decay of thorium produced completely different elements. The findings were published in a series of joint scientific communications to the *Philosophical Magazine*, resulting in the establishment of the disintegration theory of radioactive decay in 1903.[71] The ramifications of this theory were broad. It was the final blow to the conception that the atoms of the elements were simple, stable entities. The disintegration theory explained the radioactive transmutation of the elements in terms of the emission of alpha particles from the atom. Furthermore, the theory held that such transmutation of elements occurs spontaneously in nature. This had ramifications for views on the origin and evolution of substances, and could be used to explain the relative rarity and abundance of different elements, as well as why certain elements often seemed to occur naturally together. For

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[69] See Gordin, *A Well-Ordered Thing*, 215. Mendeleev was not alone in using ether theory this way: already in 1897 the British physicist George Gabriel Stokes had proposed that the uranium molecule makes a wiggle which makes the ether around it vibrate, causing the radiation; even the Curies had considered that radioactive elements were somehow 'transformers of ethereal energy'. Trenn, *The Self-Splitting Atom*, 15, 11.

[70] A detailed history of their 18-month collaboration and its context is available in Trenn, *The Self-Splitting Atom*.

[71] Cf. the timeline in Trenn, *The Self-Splitting Atom*, 4-6.

example, radium was shown to be a disintegration product of uranium, and the two would therefore tend to occur side by side.[72] Later in 1903, the nature of the mysterious alpha particles would also be identified. Now together with William Ramsay in London, Soddy proved experimentally that the alpha-particle was in fact an atom of *helium*. The element of helium was therefore produced spontaneously from other elements undergoing radioactive decay. A fundamental natural process had now been uncovered, and a new picture of matter emerged: in place of stable, immutable atoms, matter was constantly in flux, and subject to processes of evolution and decay. These processes happened spontaneously in a fundamentally undetermined manner.

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The discoveries outlined above set the stage for what Mark Morrisson has called a 'transmutational gold rush' in chemistry between 1907 and the outbreak of war in 1914.[73] The gold rush was sparked by a communication to *Nature* in July 1907, in which William Ramsay proclaimed that he had successfully transmuted copper into lithium by exposing it to 'radium emanations'.[74] The communication was very well received, and within a few months both *Nature* and *The Lancet* were publishing pieces on the final realisation of a modern alchemy, wielding the power to transmute the elements.[75] Other chemists soon followed up, enthusiastically reporting confirmation of Ramsay's results, leading to broad public attention in such outlets as *The New York Times* and *Popular Science Monthly*.[76] There was only one problem: Ramsay's transmutation would eventually appear spurious – a result of stretching the interpretation of ambiguous experimental data too far. Ernest Rutherford had found that a lack of control of the experiment was the likely source for positive results: contaminated apparatus and small but continuous air leakages were sufficient to account for the tiny amounts of the

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[72] For Soddy's views early views on the implications for a philosophy of matter, see his *Interpretation of Radium*, esp. 210-229.

[73] Morrisson, *Modern Alchemy*, 121-134.

[74] Trenn, 'The Justification of Transmutation', 57-59.

[75] *The Lancet* published an article on Ramsay's experiments with the title 'Modern Alchemy: Transmutation Realized', later in 1907. For a discussion, see Morrisson, *Modern Alchemy*, 121-123. For the praise in *Nature*, see also Trenn, 'The Justification of Transmutation', 58-59.

[76] Morrisson, *Modern Alchemy*, 122-124.

unexpected elements that were found.[77] In 1914 the enthusiasm of the chemists finally abated with the realisation that evidence for transmutation had been spurious all along.[78]

The 'age-old dream of man to manipulate the principles of matter' was, however, finally realised in 1919.[79] This year Rutherford, now at Cambridge, published four papers in *Philosophical Magazine* detailing how his bombardment of nitrogen with alpha particles (helium) had succeeded in disrupting the nitrogen atom so that it gave away a hydrogen atom and was itself transmuted into oxygen.[80] This was genuine artificial transmutation. With Ramsay's premature conclusions now forgotten, the new discovery of artificial transmutation was quickly noted by Rutherford's colleagues, including Soddy who wrote to convey his 'intense interest and admiration' for the results.[81]

MODERN ALCHEMY AND THE PROBLEM OF DISENCHANTMENT

Having considered the broad lines of the major conceptual switch in chemistry at the beginning of the 20th century, we should return to the question of how these developments relate to the problem of disenchantment. There are at first sight two points that stand out as important. First, how do we see the conceptual switch in chemistry, from a Daltonian-Mendeleevian paradigm of stable elements, to a post-radioactivity paradigm of mutable and unstable elements in terms of disenchantment?

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[77] Trenn, 'The Justification of Transmutation', 58-60.

[78] Overview in Morrisson, *Modern Alchemy*, 130-134.

[79] Trenn, 'The Justification of Transmutation', 53.

[80] In simple notation: N + He → O + H. Ibid., 71-73.

[81] Quoted in Trenn, 'The Justification of Transmutation', 73. Interestingly, Rutherford himself was less interested in the achievement of artificial transmutation, attaching more importance to the fact that he had proved the atomic nucleus to consist of hydrogen atoms. This appeared to vindicate a theory that had challenge Dalton's theory a century earlier, namely the hypothesis of William Prout (1785–1850) that all material elements were ultimately reducible to one single "protyle" (*proto hyle*, "first matter"), and, furthermore, that this *Urstoff* was in fact the hydrogen atom. In 1920 Rutherford would name the positively charged core of the hydrogen atom the *proton* – an elementary particle which has subsequently become part and parcel of the conception of matter in the physical sciences. To Rutherford, the justification of the Proutian hypothesis was the major advance of his experiment, and it was the final nail in the coffin for the 19th century conception of solid, unchanging, stable elements. Trenn, 'The Justification of Transmutation', 74; cf. William H. Brock, *From Protyle to Proton*.

Secondly, what is the meaning of the central alchemical trope in this story, harkening back to an ostensibly "pre-disenchantment" scientific culture? How is it related to the creation of emic historiographies of science?

We have seen that the advent of radioactivity sparked not only enthusiasm, but also much scepticism. This scepticism was grounded precisely in the perception that radioactivity, if correct, seemed to go against an established metaphysics of chemistry and suggest that a different physical worldview was needed. Mendeleev even likened radioactivity with spiritualism and criticised the essentially *animistic* connotations of the claim that matter was able to give off large quanta of energy, spontaneously and without external excitation, and even transmute into other elements. These were indeed serious challenges to established conceptual models. We have seen earlier that the Victorian scientific naturalists had used the Daltonian theory of matter as one of their conceptual pillars, together with thermodynamics and biological evolution. As I argued in chapter two, this naturalistic worldview was in important respects a disenchanted one, and the Daltonian conception of matter was indispensible for its consistency. The redefinition of matter ensuing from the discoveries of radioactivity thus signifies the fall of the Victorian naturalists' mode of disenchantment. It seemed above all to question the epistemic optimism that held the natural world to be completely explicable and predictable.

This is a crucial point for understanding the emergence of the alchemy trope as well. The labelling of a new field as "alchemy" implied an opposition to established chemical knowledge of the 19th century, whether that opposition was embraced or rejected. The metaphor could be seized both as a *disqualification* (implying that a proposition is absurd, or in disagreement with established knowledge), and as a *positive* categorisation of a new science positioned on an explicit opposition to aspects of established teachings. The modern alchemy discourse would typically focus on a *philosophical* form of opposition, abundant examples of which can be found in Soddy's popular writings.[82] A curious emic historiography of chemistry emerges from this rhetorical disjunction between 19th century chemistry and "modern alchemy", which is

[82] Especially in *The Interpretation of Radium*, where Soddy dwells at length on cosmological questions such as the age and origin of matter and the elements, attacking geological creationism, while defending an almost animistic view of matter, given irreducible agency and subjected to some form of evolution.

adequately summarised by the chemist Stanley Redgrove in his 1911 *Alchemy: Ancient and Modern*:

> If we were asked to contrast Alchemy with the chemical and physical science of the nineteenth century we would say that, whereas the latter abounded in a wealth of much accurate detail and much relative truth, it lacked philosophical depth and insight; whilst Alchemy, deficient in such accurate detail, was characterised by a greater degree of philosophical depth and insight; for the alchemists did grasp the fundamental truth of the Cosmos, although they distorted it and made it appear grotesque. The alchemists cast their theories in a mould entirely fantastic, even ridiculous —they drew unwarrantable analogies—and hence their views cannot be accepted in these days of modern science. But if we cannot approve of their theories *in toto*, we can nevertheless appreciate the fundamental ideas at the root of them.[83]

In short, a re-appreciation of alchemy may lend 'philosophical depth and insight' to modern science, something that had, according to the argument, been lacking in 19th century chemistry. Viewed as a modern alchemy, radioactivity gives a new depth and sophistication to modern science. It also implies that the simplistic "disenchanted" picture of the Victorian era belongs to the past.

I will end this section with an important caveat: while the alchemical discourse about radioactivity emphasises aspects of the new discoveries that go against the strictly disenchanted picture, it would be much too simple to characterise it as a full-scale "re-enchantment of chemistry". The relation between modern alchemy and "mysterious incalculable forces" is not entirely straight-forward. Research on radioactivity started, as we have seen, with the discovery of certain mysterious new substances, which behaved differently from other known substances. The mystery was then solved through careful experiment and rigorous applications of reason – one might say in the ordinary "disenchanted" fashion. However, the theoretical outcome of solving it was that *all* matter had to be rethought along lines that do not fit the epistemic dimension of disenchantment very well. This tension is aptly illustrated by Soddy in *The Interpretation of Radium*:

[83] Redgrove, *Alchemy*, vi.

> Radium, a new element, giving out light and heat like Aladdin's lamp, apparently defying the law of conservation of energy, and raising questions in physical science which seemed unanswerable, is no longer the radium we know. But *although its mystery has vanished, its significance and importance have vastly gained*. … If we now ask, why is radium so unique among the elements, the answer is not because it is dowered with any exceptional potentialities or because it contains any abnormal store of internal energy which other elements do not possess, but simply and solely because it is changing comparatively rapidly, whereas the elements before known are either changing not at all or so slowly that the change has been unperceived. *At first this might seem as anti-climax*. *Yet it is not so*. *The truer view is that this one element has clothed with its own dignity the whole empire of common matter*. The aspect which matter has presented to us in the past is but *a consummate disguise, concealing latent energies and hidden activities* beneath an hitherto impenetrable mask. The ultra-material potentialities of radium are the common possession of all the world to which *in our ignorance we used to refer as mere inanimate matter*. This is the weightiest lesson the existence of radium has taught us … .[84]

The unmasking of mysteries, at least in Soddy's eyes, had ultimately made the world *more* remarkable, even enchanted, than it had been before: Soddy's language evokes the return of animated, living nature. Matter has previously appeared in disguise; the uncovering of 'latent energies and hidden activities' concealed in matter evoke the memory of the "occult forces" and "occult properties" referred to in medieval and early modern science and philosophy.[85] The notion of 'inanimate matter' is, finally, described as stemming merely from 'ignorance': the views of an immature stage in science that is now being left behind.[86]

Although radioactivity in this sense introduced hidden incalculability, even threatened to break down the distinction between the animate and inanimate in nature, science did not thereby abandon its ambition to *manipulate* and *control* nature. Indeed, the ultimate goal of artificial transmutation was precisely to tame and control these forces in order for humanity to shape the world to its own advantage. This *utilitarian* aspect of science is also strongly present in Soddy's writings: finding a way to unleash,

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[84] Soddy, *Interpretation of Radium*, 231-232. My emphases.

[85] For an overview, see Hanegraaff, 'Occult/Occultism', 884-886; cf. idem, *Esotericism and the Academy*, 177-191.

[86] Accidentally, the rhetoric has significant affinities with that of, for example, theosophical writers. See e.g. Asprem, 'Theosophical Attitudes toward Science'; see also chapter eleven in the present study.

convert, and direct the vast deposits of energy secretly stored in matter all around us was presented as the main goal of radiochemistry. After having mused on the purely philosophical aspects, Soddy wrote that 'the unlocking of the internal stores of energy in matter would, strangely enough, be infinitely the most important and valuable consequence of transmutation'.[87] Technological applications and control could save modern civilisation from collapsing under its growing demand for energy, and lay the foundation for infinite progress.[88]

This utilitarian rhetoric was an important aspect of the modern alchemy discourse surrounding radioactivity, and it appears that the perceived technological and economic side of alchemy was just as important in the analogy-making as any views of enchanted, living nature. This obviously makes a reading of radioactivity and modern alchemy on the lines of straightforward "re-enchantment" problematic. The conclusion must be that from the purely scientific perspective, as well as from the perspective of major popularisations of the field written by scientists, radioactivity considered as modern alchemy stands in a relation to disenchantment that is highly ambiguous. The flexible manoeuvring between different aspects of the problem of disenchantment also justifies the more nuanced approach called for in earlier chapters, and particularly demonstrates the need to break the concept down into components that are not, necessarily or always, connected by historical agents.

5 Physics, Worldview, and Culture: Revisiting the Forman Thesis

In the present section we shall take a an externalist and contextualist approach that may help us understand and explain the broader cultural meanings and interpretations invested in some of the scientific developments we have considered so far. This gives us a more complete framework for assessing the roles and motivations of scientists in engaging with the problem of disenchantment. Out of the three currents that we have discussed it is above all the case of quantum mechanics that must now be approached from an externalist perspective. Concepts such as acausality, indeterminism, wave/particle duality, and complementarity have made quantum mechanics philosophically interesting and secured much popular interest. Since the second world

87 Soddy, *Interpretation of Radium*, 237.

88 See especially Soddy, 'Transmutation: The Vital Problem of the Future'.

war, it has been used as justification for a range of exotic worldviews. While there is thus little doubt that quantum mechanics exerted a great influence on other parts of culture, there are also reasons to think that the specific interpretational framework given to quantum mechanics in the 1920s and 1930s was *itself* influenced by external cultural factors. The most explicit statement of this view has been developed by historian of science Paul Forman. In the following I will give a critical assessment of Forman's case for the cultural contingency of quantum mechanics, and suggest some modifications that give us a relevant framework for assessing the problem of disenchantment in the modern physical sciences.

Forman's thesis holds that the peculiar nature of quantum mechanics and its accompanying epistemological and ontological implications were shaped in significant ways by the cultural sentiments of the Weimar republic in the aftermath of the Great War.[89] In a controversial essay from 1971, Forman argued that the extraordinary ease with which German speaking quantum physicists were willing to accept that causality had been expelled from the workings of nature becomes fully intelligible when viewed as an expression of a certain Zeitgeist in Germany following the experience of defeat in WWI, characterised by a wish to escape the terror of history and the pressure of determinism.[90] A general hostility towards science was gaining ground, based on a perception that science had not only failed in its visionary promises, but also catastrophically contributed to the horrors of the war. In the popular mind, science was increasingly confused with industry, technology, and military applications, while its philosophical outlook was perceived to be one of cold and bleak materialism, mechanism, reductionism and determinism – all taken to represent a decline of the human spirit. Significantly, Oswald Spengler's *Untergang des Abendlandes* (*Decline of the West*) was published in parallel with the development of quantum mechanics, going through 60 printings between 1918 and 1926. A total of 100,000 copies was printed in this period, equalling one third of Germany's college students at the time.[91] Spengler's pessimistic view on modern civilisation, including science, was '[a]lmost universally

[89] The thesis is developed in three articles in particular: Forman, 'Weimar culture, causality, and quantum theory'; idem, 'Reception of an Acausal Quantum Mechanics in Germany and Britain'; idem, '*Kausalität, Anschaulichkeit*, and *Individualität*'.

[90] Forman, 'Weimar culture, causality, and quantum theory'.

[91] Forman, Weimar culture, causality, and quantum theory', 30.

read in academic circles'.[92] In this intellectual climate, scientists needed to reinvent themselves. The ways in which quantum mechanics was formulated in the 1920s can thus be seen as an exercise of adaptation to a hostile intellectual environment.

In his first article on the thesis, Forman situated the many 'conversions to acausality' by leading German physicists in the period between 1919 and 1927 in context of a general scepticism toward science, and particularly what we might call a "disenchanted" stereotype of science.[93] Responding to critics of the thesis,[94] Forman has later made certain qualifications to his earlier formulations: less radical than some critics have made it to be, the basic point is simply that the actual discoveries and innovations of quantum mechanics did not *necessitate* the worldview implications and interpretations that its progenitors saw in them. Other options were available, but almost unanimously rejected in Germany. This more carefully stated version of the thesis will be taken as a starting point here.[95] I will briefly discuss the Forman thesis's claim regarding the rejection of causality, before proceeding to a criticism and a re-assessment aimed at situating Forman's thesis in the broader argument of the present work.

Causality and the Weimar Zeitgeist

As seen in the historical overview of quantum mechanics, a debate arose in the mid-1920s about whether a causal interpretation was at all possible. According to Forman, the reasons for the revolt against causality is to be found in the cultural dynamic of Weimar Germany rather than in the scientific record itself. First of all we need to acknowledge what physicists and philosophers of the period understood by "causality". This question is more complicated than it may seem on the surface. The concept of

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92 Ibid.

93 Forman, Weimar culture, causality, and quantum theory', 63-108. Forman later broadened his thesis to include some other features of broader cultural importance that quantum physicists wrote about , namely views on visualizability/picturability (*Anschaulichkeit*) and individuality. In the present chapter I will limit myself to the aspect of causality. See, however, Forman, '*Kausalität*, *Anschaulichkeit*, and *Individualität*'.

94 E.g. John Hendry, 'Weimar Culture and Quantum Causality'; Stephen Brush, 'The Chimerical Cat'; Kraft & Kroes, 'Adaptation of Scientific Knowledge to an Intellectual Environment'.

95 Also not that this version of the Forman thesis is in agreement with the theoretical discussions of chapter three, and my methodological notion of a naturalistic constructionism.

causality is connected with a number of philosophical and metaphysical problems which have been probed in numerous ways through history.[96] In different periods and contexts it has been connected with other concepts such as intelligibility, determinism, or the notion of natural law. From a historical perspective, the relation between these concepts is not fixed; however, Forman has demonstrated that all the above tended to be related to each other by German physicists in the period that concerns us here.[97] Definitions of causality tended to be expressed in terms of lawfulness: as Moritz Schlick, one of the central figures of the Vienna circle, explained in 1920, '[t]he principle of causality is … the general expression of the fact that everything which happens in nature is subjected to laws which hold without exception'.[98] Even Heisenberg explained it this way in 1930, talking about 'the idea that natural phenomena obey exact laws – the principle of causality'.[99] In contrast to this *nomological* (i.e. following laws) concept of causality the *ontological* notion of causality as "cause and effect" had already been under attack by scientists and philosophers for a very long time. Forman mentions contemporary critics of ontological causality in Ernst Mach and the positivist movement, as well as neo-Kantians such as Ernst Cassirer. One could also mention philosophers such as Henri Bergson in France and Bertrand Russell in England, with a tradition going back to David Hume's famous criticism of causality in the 18th century.[100] According to Mach and the positivists, causality in the sense of cause and effect was "metaphysical", "animistic", and "fetishistic"; it needed to be replaced by a model purely based on functional relations that could be expressed mathematically.[101] Detesting causality in the ontological sense was thus hardly controversial.

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96 A good technical overview of the metaphysics of causality is available in the *Stanford Encyclopedia of Philosophy*. See Jonathan Schaffer, 'The Metaphysics of Causation'.

97 Forman, 'Weimar culture, causality, and quantum theory', 63-70.

98 Schlick's statement opened an article on 'Naturphilosophische Betrachtungen über das Kausalprinzip', published in the prestigious journal *Naturwissenschaft*. See Forman, 'Weimar culture, causality, and quantum theory', 65.

99 Heisenberg's remark in 1930 fell as part of his introductory work, *The Physical Principles of the Quantum Theory* (1930). Cf. Forman, 'Weimar culture, causality, and quantum theory', 65.

100 See especially Russell, 'On the Notion of Cause' (1912); Bergson, *Time and Free Will* (1910 [1889]), 199-221.

101 Forman, 'Weimar culture, causality, and quantum theory', 68.

Another and related aspect of physicists' conception of causality in this period was its connection with *determinism* of the Laplacian variety.[102] Philosophers have often considered determinism and causality to be two logically distinct issues; however, physicists of the period covered by Forman's thesis tended to confuse the two to the point of identity.[103] On that premise, objecting to determinism meant objecting to causality, and vice versa.[104] Realising that determinism was very unpopular at this time, and that science was suspect on the grounds of being committed to it, the assumed connection between determinism and causality makes it easier to understand the sudden ease with which physicists accepted an acausal view of nature in light of quantum mechanics. This was, of course, irrespective of the fact that one could easily remain a determinist without believing in strict mechanistic causality, whether by teleological notions of predetermination, Leibnizian pre-established harmony, or any such philosophical device.

Conversions to acausality were numerous. In 1926, Max Born expressed that he was 'inclined to abandon determinedness in the atomic world', and was soon followed by colleagues such as Sommerfeld and Jordan.[105] The insistence on indeterminacy and acausality was, however, much more explicit in Heisenberg's 1927 article on the uncertainty principle. Even if that principle could be read as a *methodological* problem arising from imperfections of measurement, as already seen, the young physicist concluded his article with the bold statement that 'quantum mechanics establishes definitively the fact that the law of causality is not valid'. Heisenberg makes Born's more carefully stated "inclination" into a full-blown categorical statement.[106] The claim is now that quantum mechanics shows nature *itself* to be inherently and fundamentally acausal. This interpretation eventually gained a hegemonic status in the Copenhagen interpretation, despite much criticism by people such as Einstein. Explaining why this

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[102] See e.g. Pierre-Simone Laplace, *Philosophical Essay on Probabilities*, 2, quoted in chapter one.

[103] For an overview of how different relations between causality and determinism have been drawn up in physics since the early modern period, and how definitions of both have changed with broader conceptual changes in physical science, see Friedel Weinert, *The Scientist as Philosopher*, 193-276.

[104] Forman, 'Weimar culture, causality, and quantum theory', 69.

[105] In Forman, '*Kausalität*, *Anschaulichkeit*, and *Individualität*', 336. For a thorough discussion of such "conversions" to acausality, see idem, 'Weimar culture, causality, and quantum theory', 74-90.

[106] Forman, '*Kausalität*, *Anschaulichkeit*, and *Individualität*', 336.

debate was settled the way it was is what Forman's thesis tries to achieve, and it does so by questioning the necessity and "naturalness" of the acausal interpretation:

> There is great disparity between quantum mechanics, per se, and the world-view implications immediately ascribed to it. Quantum mechanics is merely a statistical theory. As Einstein repeatedly but vainly emphasized, it cannot be regarded as a complete description of an independently subsisting microscopic world. Nor can it be regarded as an appropriate conceptual basis for describing our macroscopic world, where, unquestionably, we deal with individual objects and events, not statistical ensembles. Thus even categoric statements about the invalidity of the law of causality in the *physical* world go much too far, *not least because they slur over the fact that quantum mechanics is a deterministic theory of probabilities*. As for the still farther-reaching world-view implications ascribed to quantum mechanics – that it ensures free will, or the impossibility of a physicochemical explanation of life – one must say that *these are completely unwarranted*.[107]

Nevertheless, acausal interpretations not only emerged as intriguing possibilities, but immediately swept across the German physics community and were broadly accepted within few years. By contrast, physicists in France, Great Britain, and North America largely remained oblivious about such interpretations, and were often hostile when encountering them.[108] When American physicists got interested in the new quantum mechanics in the late 1920s, they were typically left cold by the so-called "Copenhagen spirit" of its missionaries.[109] Following a visit in Göttingen in 1926, the American atomic physicist Robert Oppenheimer recalled his encounter with the 'fantastically impregnable metaphysical disingenuousness' of German quantum physicists.[110] Similarly, although somewhat earlier, a letter correspondence between the American experimentalist and Nobel laureate Albert Michelson and British ether physicist Oliver Lodge in 1923 shows both expressing concerns about the "discontinuity" apparent in the developing quantum theory, even hopes that an enhanced ether theory

[107] Ibid., 336-337. Italics added.

[108] Forman, '*Kausalität*, *Anschaulichkeit*, and *Individualität*', 337; cf. idem, 'The Reception of an Acausal Quantum Mechanics in Germany and Britain', 23-38.

[109] Kragh, *Quantum Generations*, 172; Heilbron, 'Earliest Missionaries of the Copenhagen Spirit'.

[110] Alice Smith & Charles Weiner (eds.), *Robert Oppenheimer: Letters and Recollections*, 100.

may resolve the problem along with the strange implications of Einstein's relativity theories.[111]

Shortly put: there seems to have been something about Weimar Germany and its cultural sphere that made scientists from this area see something in quantum physics which others did not – or to eagerly accept something which others would remain hesitant about. Forman's claim is that this something was a specific cultural condition arising after Germany's military defeat and political and economic collapse, which may generally be characterised by three main features:

1) An anti-intellectualist, neo-romantic irrationalism, celebrating the spontaneous, intuitive, immediate, and "authentic", in place of the contemplatively "rationalistic";
2) An antipathy towards causality and mechanism in favour of a largely anti-modern *Lebensphilosophie*;
3) Antagonism towards natural science, particularly physics. Theoretical physics was seen as epitomising all that the neo-romantic *Lebensphilosophie* rejected; furthermore, physicists and scientists were seen as agents of the debauched, industrial, technocratic "West".[112]

These features resonate with the concept of "Occidentalism" – the mirror image of Orientalism – denoting a stereotyped, negative, polemical image of "the West", based largely on romantic ideas, which spread in Germany but also outside of Europe during the first decades of the 20th century.[113] In their discontent with modernity, significant

[111] Michelson to Lodge, August 18, 1923; Lodge to Michelson, August 30, 1923. Oliver Lodge papers, MS App. 89/71, University College London, Special Collections.

[112] These traits of the 'hostile intellectual environment' of German inter-war physicists are discussed at length in Forman, 'Weimar culture, causality, and quantum theory', 8-37, and in strongly condensed form in Forman, '*Kausalität*, *Anschaulichkeit*, and *Individualität*', 337-338.

[113] See Ian Buruma & Avishai Margalit, *Occidentalism: The West in the Eyes of Its Enemies*; cf. James G. Carrier (ed.), *Occidentalism: Images of the West*. Although this is not the place to enter into a deep discussion of these issues, one should note that the concept of Occidentalism has garnered some controversy. Particularly, Buruma and Margalit's model in which the stereotypes of the West are seen as produced by Western discourses struggling with modernity, particularly in rejections of the Enlightenment in German romanticism, other scholars have objected that this view is *itself* too

forces within German cultural life and intelligentsia summoned up a mono-causal image of all that was wrong in society, an image in which a stereotyped "modern West" was decried as cold, heartless, and mechanical, as well as morally degenerate. Quantum mechanics was forged in a cultural milieu that was generally hostile to the perceived "modern" ideals associated with science and the academy. This Weimar period Occidentalism was epitomised in Spengler's *Decline of the West*. Indeed, a condensed formulation of Forman's thesis on the rejection of causality is that physicists 'largely participated in, or accommodated their persona to, a generally Spenglerian point of view'.[114] The rejection of causality thus followed from Occidentalist biases of the Spenglerian type. The hope was to create a new physics, a whole new philosophy of nature, based on principles more friendly to *Lebensphilosophie*.

In concluding this presentation of the Forman thesis, I should add a cautionary note. Even though Forman states that his 'conclusion is admittedly radical',[115] externalist interpretations may always be taken in a variety of stronger and weaker senses. Forman prefers to describe the thesis as a 'meta-meta statement' about 'the physicists' statements about their descriptions of reality'.[116] Perhaps even more precisely, it could be characterised as a "meta-meta-meta statement" about (level 3) physicists' *philosophical* interpretations of (level 2) their *formal* descriptions of (level 1) the reality they measure in experiments (figure 5). It is not so much the "raw" data collected by scientists that is being explained as a contingent by-product of history, not even the data mediated through experimental devices, technical language and statistical calculations. It is rather the thoroughly "cooked" *interpretations*, the philosophical and even spiritual implications that are, in some sense, culturally determined.[117]

Furthermore, we have seen Forman stress that such cultural contingency is fully possible since the quantum mechanical theory is sufficiently open-ended on several points of interpretation. On this reading, the Forman thesis does not appear radically extravagant. It leaves, so to speak, the "rational component" of measurement,

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Eurocentric, and a more dynamic east-west relation should be considered. For this view, see especially Alastair Bonnett, *The Idea of the West*.

114 Forman, 'Weimar culture, causality, and quantum theory', 55.

115 Forman, '*Kausalität*, *Anschaulichkeit*, and *Individualität*', 344.

116 Ibid., 344, 347 n.44.

117 Cf. the distinction in Claude Lévi-Strauss, *The Raw and the Cooked*.

experiment, and discovery relatively autonomous, while identifying a cultural superstructure which is *constrained* but not *determined* by the rationality of science.

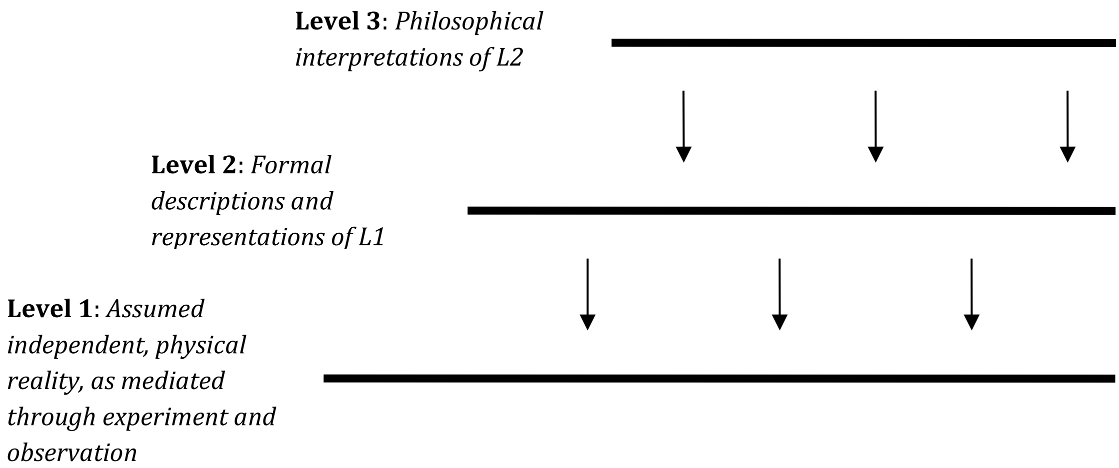

Figure 5: Three levels of scientific interpretation. On my reading, the Forman thesis is a claim about level 3 only.

Forman Revised: Criticisms and Re-Evaluation

Writing in 1980 John Hendry noted that no general agreement on the Forman thesis had emerged in the history of science community, but that there was a dominant feeling of 'case not proven'.[118] More recently, Helge Kragh took the opportunity to revisit Forman's thesis in his comprehensive history of 20th century physics.[119] Kragh agrees that mathematicians and theoretical physicists responded to the Zeitgeist, notably, in his eyes, by refraining from justifying their vocation in terms of *utility*. The utilitaristic appeal had been very helpful in the campaign to professionalise the sciences in the 19th century, but now, under quite different societal conditions, it was exchanged for a strategy that portrayed physics as "culture".[120] Kragh agrees that the repudiation of causality was not strongly rooted in experimental or theoretical developments, but

[118] Hendry, 'Weimar Culture and Quantum Causality', 155. Important early criticisms were made by Hendry, and Kraft & Kroes, 'Adaptation of Scientific Knowledge to an Intellectual Environment'. These provided the basic arguments that have been reiterated by later critics.
[119] Kragh, *Quantum Generations*, 151-154.
[120] Ibid., 153.

could rather be seen as expressions of a vaguely "Spenglerian" worldview. Nevertheless, he insists there are 'good reasons to reject the suggestion of a *strong* connection between the socio-ideological circumstances of the young Weimar republic and the introduction of acausal quantum mechanics'.[121] In order to clarify my own position, and identify what seems to be certain common misunderstandings and misreadings of the Forman thesis, I will proceed to discuss Kragh's objections and defend Forman against some of them.

Kragh brings up seven points against a "strong" version of the Forman thesis; three of which seem to miss the target or attack a straw man, while the other four reflect genuine challenges that should not go unnoticed. Starting with the weak points, Kragh argues that Forman's thesis is defective because: (1) acausality 'and other Zeitgeist-related problems' were discussed in public lectures and addresses rather than in actual scientific papers; (2) cultural adaptations were concerned with the *evaluation* rather than *content* of science; (3) the young German creators of quantum mechanics were 'more interested in their scientific careers than in cultural trends'.[122]

I find these three objections to miss the point. Points (1) and (2) fail as serious criticisms and can in fact largely be seen as *consistent* with the reading of Forman that I have offered above. First of all, the thesis does *not* claim that the "rational component" was significantly affected by the cultural condition, only that its philosophical and ideological superstructure was.[123] Hence one would not necessarily expect to find 'Zeitgeist related problems' expressed in the actual daily work of physicists, as reflected in scientific papers. And yet, despite our expectations of finding an engagement with "worldview implications" primarily in popular science or (amateur-) philosophical literature, we *do* also find it in some of the most important scientific papers. This only strengthens the case for the Forman thesis, even though it was not necessary for the thesis as such to hold. Similarly, if (3) was shown correct, and young scientists only

[121] Ibid. Emphasis added.

[122] Ibid., 153-154. My numeration of Kragh's critical points (which can all be found in the earlier literature as well, but are conveniently summarised here) is not the actual order in which they are put forward in the text. I have changed their order to differentiate the relevant objections from those I feel are less on the spot.

[123] These two points were originally raised by Hendry, who made much out of the value/content distinction. See, Hendry, 'Weimar Culture and Quantum Causality', 157-60.

played on cultural trends as strategies to advance their careers, this would still remain a strong case for the importance of cultural context on the actual direction of scientific work. “Genuineness” is not required for the argument to work. The objection can thus only be used to adjust our perspective on *how* and *why* cultural context was able to drive scientific developments, by emphasising the personal agendas of young, career-conscious scientists.

The rest of Kragh’s objections are more to the point, and raise serious criticisms against the *causal robustness* of Forman’s thesis. It is indeed a problem for a strong reading that (4) leading physicists such as Sommerfeld, Bohr, Einstein, Planck and others were expressed critics of the Zeitgeist, and (5) that the first acausal model for quantum theory, the 1924 Bohr-Kramers-Slater radiation theory mentioned earlier, was formulated by a Dane, an American and a Dutchman: not a single Weimar republic scientist was involved. Even more importantly, this model was initially *not* accepted in Weimar Germany. Also contrary to Forman, Kragh notes that (6) many physicists saw purely scientific reasons for dispensing with causality in microphysics, and (7) that there was already a sense of crisis in 1920s physics rising from “internal” considerations concerning anomalies in existing atomic theories.

These are all valid points, and warn against overstating the importance of the broader cultural context. In the final analysis, I hold that a weak version of Forman’s thesis remains plausible as long as one is ready to supply the socio-historical “externalist” account with “internalist” perspectives on the one hand, and *additional* external factors on the other. For example, Bohr’s central role in Copenhagen already points us towards quite different external constraints than the Weimar Zeitgeist and *Lebensphilosophie*. In fact, the question of who were the philosophical influences on Bohr has generated a literature of its own, and the Danish philosopher Harald Høffding (1843–1931) has been put forward as especially important.[124] Bohr studied philosophy with Høffding, and it was through him that the physicist first became acquainted with Kierkegaard and Kant. It has been suggested that the influence of Kierkegaard appears in Bohr’s formulation of complementarity, and that the Kantian views on time and space as categories of perception accounts for some of the fundamental differences between

[124] E.g. Jan Faye, *Niels Bohr*.

Bohr and Einstein.[125] In addition to this, we have already seen the importance of logical-positivist epistemological sentiments on the formulations of quantum mechanics in the 1920s, a position which was also based on neo-Kantianism. In short, several philosophical and cultural influences come together to form an intellectual reservoir from which the Copenhagen school would draw. The philosopher of science Mara Beller has even made the case that the peculiarities of the Copenhagen interpretation are, at least in part, the result of the eclecticism of physicists acting as amateur philosophers.[126] In her view, 'the inconsistencies [in Bohr's writings] are genuine', and stem from defects in Bohr's capacity as a philosophical thinker. The failure of later scholars to admit the flaws of Bohr's reasoning is, in Beller's view, due to a form of hero worship.[127]

Summing up, I largely follow Hendry who admitted that '[p]hysicists *were* influenced by the crisis-consciousness of post-war Europe and by the attitudes characteristic of the Weimar republic',[128] but remained sharply critical of the simplistic, mono-causal picture drawn up by Forman's social determinism. It is hard to disagree that 'no single set of influences – internal, social, philosophical, psychological, etc. – can be taken independently of the others'.[129]

6 Conclusion: the Forman Thesis and the Problem of Disenchantment

An approach to the history of physics between the wars on the lines of a revised, nuanced, and expanded Forman thesis is a promising way to tie together the major concerns of this book, namely a reconsideration of the disenchantment thesis and a

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[125] Einstein had, of course, overthrown the Newtonian vision of absolute time and space, but had equally steered theorising about these concepts away from the Kantian theory of "categories of the understanding", in a new ontologising direction. See Faye, *Niels Bohr*; cf. James T. Cushing, *Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony*, 99-103, 244 n.29, 245 n.43. A perspective which grants Høffding less importance is presented by David Favrholdt, *Niels Bohr's Philosophical Background*. For the philosophical dimension of space and time, and the implications of the Einsteinian revolution, see Kennedy, *Space, Time, and Einstein*.

[126] Beller, *Quantum Dialogue*, 270-276.

[127] Ibid., 275.

[128] Hendry, 'Weimar Culture and Quantum Causality', 171.

[129] Ibid.

relocation of the esoteric on the intersection of science and religion. To conclude the chapter I will now bring these questions to the fore, and assemble the threads that have been explored so far. My argument comes together in four different but connected points, which can be summarised as follows:

1) The trends in inter-war physics which Forman has interpreted as conversions to a generally Spenglerian worldview can better be seen as struggles with the "problem of disenchantment";
2) While particularly strong in Germany between the wars, for historically specific reasons, these concerns were much broader, and can also be traced to other scientific discourses as well, including interpretations of radioactivity in the French and Anglo-American contexts *before* the Great War;
3) Besides implying the contestation of disenchantment's main dimensions, these discourses led to the foundation of specific emic historiographies of science that connected up with the memory of "esotericism" and "rejected knowledge" as well as attempts to redefine the identity of science;
4) These encounters helped spawn new fields of esoteric/religious speculation and new natural theologies, some of which have later become very influential. An example of the latter is found in the emergence of what may be called "quantum mysticism".

THE PROBLEM OF DISENCHANTMENT IN PHYSICS

It is intriguing to note that the difficult academic climate which Forman describes is also the context in which Max Weber gave the lecture in which he set forth the thesis on disenchantment and the intellectual sacrifice. While I have discussed at length how disenchantment may be construed as a problem to which people have responded in a variety of ways, we may also view the original formulation of disenchantment as being *itself* a response to the crisis-consciousness spreading in Germany after the Great War. Explicitly critical of the Spenglerian *Lebensphilosophie*, Weber's view of disenchantment and modern science's marked role within it resonate with some of the broader views on what kind of reality science was uncovering.[130] While this historisation of Weber is interesting in itself, we should concentrate on applying the revised analytic perspective that we extracted from the concept of disenchantment in previous chapters. When we do that, the tendencies discussed by Forman may all be seen as struggles with the problem of disenchantment.

To the extent that the physicists we have discussed were driven by a reconsideration of the cultural *value* of the physical sciences, this may be characterised as an explicit rejection of the disenchanted view of science and the world. For most of those involved, the rejection concerned at least two of the three dimensions of disenchantment identified in chapter one. The core of the Copenhagen interpretation, following Heisenberg's uncertainty principle and Bohr's principle of complementarity, represented a radical break with the epistemic optimism of the disenchanted view. In Heilbron's apt description, '[e]nthusiastic resignation became the Copenhagen spirit'.[131] Furthermore, we have seen that the physicists of the Copenhagen spirit were too eager to philosophise to take the "pessimistic" dimensions of disenchantment seriously: implications for value and meaning were commonly addressed, for example in attempts to use quantum physics to defend free will, or to use complementarity to argue the irreducibility of organic life, consciousness, and human experience. In fact, the extension of quantum mechanics to the life sciences became a general trend in the 1930s and 1940s. Many of Bohr's thoughts on the issue were published in the collection of lectures and essays entitled *Atomic Physics and Human Knowledge* (1958), with essays such as 'Light and Life' (originally 1933), 'Natural Philosophy and Human Cultures' (1938), and 'Atoms and Human Knowledge' (1955). Partially inspired by Bohr, Pascual Jordan attempted to create a "quantum biology" allied to vitalistic conceptions of life in the 1930s, even fronting it as a politically correct biology for the Third Reich.[132]

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[130] Cf. the discussion in chapter one.

[131] Heilbron, 'The Earliest Missionaries', 224.

[132] See, Jordan, 'Quantenphysicalische Bemerkungen zur Biologie und Psychologie'; idem, *Die Physik und das Geheimnis des organischen Lebens* ; cf. Richard H. Beyler, 'Targeting the Organism'. More famously, Erwin Schrödinger's *What Is Life*? (1944) inspired many physicists to take up molecular biology, and may even have played a significant role in the discovery of the double helix structure of the DNA molecule. See e.g. Robert Olby, *The Path to the Double Helix*; cf. E. J. Yoxen, 'Where Does Schroedinger's "What Is Life?" Belong in the History of Molecular Biology?'

When it comes to the metaphysical dimension of disenchantment the Copenhagen physicists were more ambivalent. On the one hand, their official stance was one of instrumentalism and positivist anti-realism. They claimed to eschew metaphysics, mimicking the intellectually fashionable rhetoric of the Vienna circle.[133] On the other, however, the physicists utterly failed to convince the Vienna circle philosophers and seem at times to slip down the slope from radical epistemological reflections to *de facto* metaphysical claims about the nature of reality and the (un)reality of nature.[134] Again Jordan provides the most extravagant example: the attempted annexation of biology and psychology led him not only to defend a quantum-based vitalism, including speculations on Lamarckian evolution, but he also explored the possibilities for explaining telepathy and clairvoyance through a synthesis of quantum mechanics and psychoanalysis.[135] Supporting Nazi ideology, "Germanic" culture and *Lebensphilosophie* in the 1930s, Jordan was to a much larger degree than the other Copenhagen natural philosophers part of what might be called a particularly German "holistic milieu"[136] in

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[133] Cf. Martin Puchner, 'Doing Logic with a Hammer: Wittgenstein's *Tractatus* and the Polemics of Logical Positivism'.

[134] See the many articles and short comments on various aspects of quantum mechanics in *Erkenntnis* 5.1 (1935). The Vienna circle positivists found Jordan's metaphysical ideas and excursions into vitalism particularly preposterous, as evinced by six essays and communications dealing with his work, including comments by Moritz Schlick, Otto Neurath, and Hans Reichenbach.

[135] Jordan's quantum mechanical defence of vitalism was also attacked in *Erkenntnis* in 1935; see Edgar Zilsel, 'P. Jordans Versuch, den Vitalismus quantemechanisch zu retten'. Jordan's views on parapsychology were published in 1936 in *Zentralblatt für Psychotherapie*, with the title 'Positivistische Bemerkungen über die parapsychologischen Erscheinungen'.

[136] The term "holistic milieu" has in recent years been used to denote networks connecting various types of alternative spirituality in the West that tend to emphasise "holistic" worldviews, "holistic" medicine, and "holistic" science. See e.g. Paul Heelas & Linda Woodhead, *The Spiritual Revolution*; Heelas, 'The Holistic Milieu and Spirituality'. The rhetoric in German culture preceding and during the Nazi period, including in the so-called "new German medicine" (emphasising e.g. "traditional" herbal remedies over and against "materialistic" [and, moreover, "Jewish"] science-based medicine), the "deutsche Physik"-movement, and organicism and holism in biology, psychology, as well as in social and political theorising, has several points of connection with the contemporary holistic milieu when it comes to the cultural rhetoric and projected views of "the West", "Western science", "materialism", "reductionism", and so on. While applying this term to the German Nazi period is not meant as a guilty-by-association argument against these contemporary practices, one cannot deny that a comparison highlights some very

science, with obvious metaphysical interests. Jordan also seems to have been an originator of some of the common "mystical" and "spiritual" connotations of quantum mechanics when he claimed that the problematic measurement process of quantum phenomena not only implied a fundamental uncertainty due to intervening with the objects observed, but that the act of observation itself *created* those phenomena.[137] Varieties of this claim, which advances from pure empiricism to imply a subjective idealist metaphysics, has later become extremely wide-spread in "New Age" interpretations of quantum mechanics.[138] While they may not have taken the explicit form of a new metaphysics in Jordan's own writings, we recognise a considerable tension with the metaphysical scepticism of the disenchanted view.

The Esoteric Connection (I): Creating Emic Historiographies

I have already noted that the presence of an anti-modern, romantic, Weimar republic Zeitgeist is not enough to explain the interpretations of quantum mechanics that were created in this period: other contexts must also be explored. One additional context that has yet to be explored systematically is the presence of *esoteric* discourse in and around the articulations of quantum mechanics.[139] As documented by historians such as James Webb and Nicholas Goodrick-Clarke, esoteric and occult ideas blossomed in the cultures of the Weimar republic and the early Third Reich, and influenced the political and cultural establishments of the era.[140] There is, in other words, an undeniable esoteric dimension to the cultural "zeitgeist" that Forman uses to explain the emergence of quantum mechanics.

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interesting and suggestive cultural affinities. See e.g. Anne Harrington, *Reenchanted Science*; for Jordan's place in this broader cultural-scientific milieu, see Richard E. Bayler, 'Targeting the Organism', 252-253.

[137] Jordan, 'Quantenphysicalische Bemerkungen zur Biologie und Psychologie', 228. Cf. Jammer, *Philosophy of Quantum Mechanics*, 161-162. The idealistic tendencies of some quantum physicists and cosmologist of this period was also criticised by the Vienna circle; see e.g. Philipp Frank, 'Zeigt sich der modernen Physik ein Zug zu einer spiritualistischen Auffassung?' See also my discussion of "quantum mysticism" in chapter seven.

[138] E.g. Amit Goswami, *The Self-Aware Universe*; Deepak Chopra, *Quantum Healing*.

[139] "Esotericism", "the esoteric", and "esoteric discourse" are problematic terms that have been used in a variety of ways in academic scholarship. I will discuss this concept at some length in chapter ten. Cf. Hanegraaff, *Esotericism and the Academy*.

[140] See e.g. Webb, *The Occult Establishment*; Goodrick-Clarke, *The Occult Roots of Nazism*.

What was the precise significance of this esoteric dimension for new articulations of science in the period? I argue that it was first and foremost important for the creation of emic historiographies, positioning science in narratives that dissociated it from a cold-hearted and mechanistic "West" imagined by Occidentalist discourse. As Forman noted, the Spenglerian vision of science was that it should return to its 'spiritual home': 'the fate and the salvation of physics [was] a reunification of thought and feeling, a self-discovery of physics as a fundamentally religious-anthropomorphic expression'.[141] Forman also gave rich quotations from lectures and papers by leading physicists, showing how a yearning for the 'spiritual home' of Western science manifested precisely in references to historical esoteric discourses. For example, Forman quotes Richard von Mises in his introductory lecture at the Technische Hochschule in Dresden in 1920, talking about 'new intuitions of the world' – implying among other things that atomic physics has once again taken up 'the question of the old alchemists' – and that 'numerical harmonies, even numerical mysteries play a role, reminding us no less of the ideas of the Pythagoreans than of some of the cabbalists.'[142] A similar appeal to the mysterious and enchanted past of science is found in Arnold Sommerfeld's public address to the Bavarian Academy of Sciences in 1925, where the impenetrable new mathematical foundations of physics were given a spiritual flare:

> hand in hand with this turn toward the arithmetical goes a certain inclination of modern physics towards Pythagorean number mysticism. Precisely the most successful researchers in the field of theoretical spectra analysis – Balmer, Rudberg, 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 revitalized.[143]

These exclamations are primarily to be seen as expressions of an extravagant and positive "orientalising" rhetoric.[144] The choice to throw science in an "esoteric" light

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[141] Forman, 'Weimar culture, causality, and quantum theory', 37. Cf. Spengler, *The Decline of the West*, 427-428

[142] Von Mises quoted in Forman, 'Weimar culture, causality, and quantum theory', 49.

[143] Sommerfeld quoted in ibid., 50.

[144] Cf. Gerd Baumann, 'Grammars of Identity/Alterity', 25-27; Hanegraaff, *Esotericism and the Academy*, 374-375.

to a broader audience reveals something important about the cultural *positioning* scientists were aiming to achieve. We notice in this positioning, and particularly in the strategic use of history that it employs, the beginning of the kind of "emic historiography of science" that casts modern science as returning to an "enchanted" past. References to alchemists, Pythagoreans, and cabbalists appear to be used precisely to counter the view of science epitomised by the disenchanted perspective: it appears important for these physicists to show that science is more than the summation and systematisation of cold facts, that it does not bespeak a deterministic and nihilistic world. On the contrary, science is thought to open the door for something deeply meaningful, even numinous. Intriguingly, this identity is hinted at by connecting science with the popular memory of pre-modern, "occult science", as if a reference to knowledge that has historically been "rejected" by the establishment would help placing science in a better public light in a culture that was sceptical of the "Western modernity".[145] This strategy is found far beyond Weimar culture. In the context of radioactivity, an alchemical discourse playing on the same strings appeared about a decade before the Great War. In the German case more than in the Anglo-American one, however, the historical perspective that emerges bears a striking familiarity with the "re-enchantment paradigm" of the latter part of the 20th century, which we discussed in chapter two.

My conclusion is that this kind of emic historiography of science, which has later become central to new religious and popular discourses on science, has its roots in inter-war scientific discourse, especially in the attempts of scientists to reframe their profession as "culture", and distance themselves from easy associations with a "disenchanted worldview" where science merely plays a utilitaristic role, connected to industry, finance, and the military.[146] Considering this ambition it is ironic that the atomic physics made possible by radioactivity and quantum theory would soon be at the

[145] The logic here is that of a partial and strategic *inversion* of the narrative of "rejected knowledge" that has recently been described by Hanegraaff as constituting an important dimension of the construction of identity for Western academic culture. Cf. Hanegraaff, *Esotericism and the Academy*, esp. 153-256.

[146] For the influence of this sort of thinking on post-war physics, see David Kaiser, *How the Hippies Saved Physics*. It is notable that the inter-war origins of central features in this emic historiography was overlooked by John Brooke and Geoffrey Cantor, who delivered a strong attack on the historiography of New Age science. See Brooke & Cantor, *Reconstructing Nature*, 75-105.

foundation of the largest military science program ever produced: the Manhattan Project.

The Esoteric Connection (II): Conceptual Developments

In addition to forming a basis for new historical narratives emphasising opposition to "disenchanted" science, what other relations do we find between esoteric discourse and new articulations of science? We have no evidence of leading figures being directly involved with explicitly esoteric groups. The popular writings of quantum physicists of the period did, however, supply materials that were ripe for esoteric interpretations, and would lead to the creation of new esoteric concepts. Bohr did at times see himself as a kind of prophet of an emerging religion of complementarity, while Jordan linked quantum physics not only to vitalism, but to the "occult" faculties of clairvoyance and telepathy as well.[147] After coming under fire from sceptical colleagues, however, Bohr felt the need to explicitly repudiate 'mysticism, antirational vitalism, and acausality construed in favor of spiritualism' during a conference in 1936, sponsored by the Vienna circle.[148]

Bohr's disciples were less discreet. The attempted marriages of quantum mechanics with psychoanalysis and analytical psychology by both Jordan and Pauli did spawn something close to new esoteric conceptions.[149] Both of these children of the Copenhagen spirit went into psychoanalysis,[150] and both had contact with Carl Gustav Jung, discussing the connections between complementarity and the psychoanalytic process. The collaboration between Jung and Pauli, which culminated in their co-authored *Naturerklärung und Psyche* in 1952, is the better known and influential example.[151] In their book, the physicist and the psychoanalyst came together around the concept of *synchronicity*, which Jung had started to develop in a less systematic fashion

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[147] Heilbron, 'The Earliest Missionaries', 223, 216.

[148] Ibid., 218-219.

[149] See ibid., 226-229; cf. Gieser, *The Innermost Kernel*.

[150] Heilbron, 'The Earliest Missionaries', 226-227.

[151] The volume consisted of two essays, one written by Jung and one by Pauli. See Jung, 'Synchronizität als ein Prinzip akausaler Zusammenhänge'; Pauli, 'Der Einfluss archetypischer Vorstellungen auf die Bildung naturwissenschaftlicher Theorien bei Kepler'. For a critical assessment of the Jungian reading of the Kepler and Fludd debate which Pauli offered in his chapter by a professional historian of science, see Robert Westman, 'Nature, Art, and Psyche'.

in the late 1920s.[152] The basic concept that "synchronicity" tried to capture was the experience of "meaningful coincidence". These were described as relations between certain "inner" states of mind and "outer" events that seemed to reflect them, or as a sudden clustering of similar occurrences in a short temporal period, appearing meaningful in light of entirely personal experiences. Judging from his own clinical practice, Jung found experiences of synchronicity to be very common. But what to make of them? As amazing and meaningful as they were, Jung reasoned that such correlations could clearly not be due to any type of causal relation, for example through some mysterious force, law, or mental capacity that directed things to the right place at the right time. Something of that sort had, in fact, been suggested by the Austrian zoologist Paul Kammerer (1880-1926). After compulsively writing down all meaningful coincidences that happened to him, Kammerer formulated a "law of seriality", and posited the existence of a gravity-like "force", attracting "likes" in some mysterious fashion.[153] Jung cited Kammerer's concept, but took a different path by describing synchronicity as a completely 'acausal connecting principle'.[154]

Jung's concept first appeared in print in a foreword to Richard Wilhelm's translation of the Chinese *I Ching* in 1930, where he sought to define the *modus operandi* of its divination practice.[155] Jung claimed that synchronicity was a way of organising events and experiences that was fundamental to what he called 'Chinese science', and, moreover, completely different from that of 'Western science'. While the Western mentality ordered and correlated events based on temporal timelines driven by causality, Chinese "science" was based on simultaneity, and the correspondence between those qualities that present themselves simultaneously.[156]

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[152] It first appears in seminar notes from 1928 discussing the difference between "Western" and "Oriental" ways of thinking. See Gieser, *The Innermost Kernel*, 277. For an English translation of Jung's more mature article on synchronicity, see Jung, *Synchronicity*.

[153] For a discussion of Kammerer's theory, see Arthur Koestler, *The Roots of Coincidence*, chapter three. Koestler also wrote a scientific biography of Kammerer. See Koestler, *The Case of the Midwife Toad*.

[154] Jung, *Synchronicity*, 8-10.

[155] For the popular English version, see Wilhelm & Carl Barnes (trans.), *The I Ching or Book of Changes*. The first English edition was published in two volumes in 1950. The more popular single-volume third edition was published in 1967, amidst the peak of the countercultural movement of the 1960s. Cf. Michael Fordham, 'Editorial Preface', vii.

[156] Jung, 'Foreword'; cf. Gieser, *The Innermost Kernel*, 277-279.

The collaboration between Jung and Pauli only begun in 1948, and thus after the period that concerns us here.[157] It is nevertheless pertinent to mention it, since the episode reflects a tendency already present in the culture surrounding the development of quantum mechanics before WWII, building on the conceptual foundations formed in that context. The significance of Jung and Pauli's collaboration is precisely that synchronicity is one of few new esoteric concept to emerge out of the 20th century, representing an innovation, perhaps, of the old doctrine of correspondences and related notions of pre-established harmony.[158] What is significant for us here is that Pauli's increasingly broadening understanding of acausality and complementarity in physics contributed to the shaping of this esoteric concept. Pauli informed Jung about the latest science, worked to refine the psychoanalyst's understanding of it, and moved him in the direction of aligning the concept more closely with physics. This influence was duly noted by Jung, who could draw on Pauli's input when concluding his essay with a reflection on synchronicity's relevance for 'the scientific worldview'.[159]

While Pauli would remain critical of Jung's understanding of quantum mechanics,[160] he could at least grant this much: in the same way as the acausality of individual events in the micro-world disappears in statistics, and deterministic "classical" mechanics takes over, the unique and special *meaning* of synchronistic events similarly cannot be captured by statistical methods. Meaning is a property that disappears with quantity. The most important case for this, made by both Jung and Pauli, concerned parapsychology.[161] Jung spent a substantial part of his 1952 essay on synchronicity explaining how the experiments of J. B. Rhine at Duke University on

[157] For a description of the development of this collaboration, based on Jung and Pauli's letter correspondence, see Gieser, *The Innermost Kernel*, 281-298. The two had, however, been in correspondence for a decade and a half, since 1932. For a published version of their correspondence, see Mayer (ed.), *Atom and Archetype*.

[158] For a concise overview, see Jean-Pierre Brach & Wouter Hanegraaff, 'Correspondences'.

[159] Jung, *Synchronicity*, 89-103.

[160] Cf. Gieser, *The Innermost Kernel*, 283-284.

[161] Pauli even kept contact with the German parapsychologist Hans Bender, whom he met and discussed the parapsychological relevance of synchronicity with in 1957. See Gieser, *The Innermost Kernel*, 285. For both Jung's and Pauli's views on parapsychology, see e.g. ibid., 284-287, 291. See also my discussion in Part Three, especially the conclusion to chapter eight.

effects of "extra-sensory perception" could be seen in light of synchronicity.[162] The fact that mechanistic accounts of telepathy and clairvoyance had not proved fruitful opened the possibility that something genuinely "acausal" and synchronistic was going – as if the minds of the "reader" and the "sender" in a telepathy experiment did not really *communicate* with each other, but rather *corresponded* in thoughts and mental images. Jung made similar arguments for various mantic techniques, especially the *I Ching*, as we have seen, but also for astrology. Though Pauli was far from impressed by this particular use of the concept,[163] Jung himself included a series of experiments on astrology as part of his case for synchronicity.[164] However, they both agreed that if these phenomena were truly synchronistic, one would have a case against the very attempt to capture their effects by scientific research using statistical tools. The synchronistic effect is by definition particular and unique. When one goes about adding greater quantities of cases, the effect will disappear.[165]

This case is important for analysing the relations between science and esotericism, for two reasons. First, it is not unreasonable to interpret Jung as an esoteric thinker. As Wouter Hanegraaff has argued, he may be seen as someone who attempted to revive German romantic *Naturphilosophie*, and with it a way of approaching nature which bears several strong points of resemblance to early modern esoteric discourse.[166] In addition, of course, there is Jung's re-invention of "spiritual alchemy", his fascination with "the East", the *I Ching*, astrology, and parapsychology, not to mention the exceptional revelatory works he wrote, including the only recently published *Red Book*, or *Liber Novus*.[167] Secondly, the concept of synchronicity is a central part of Jung's esoteric trajectory. With it, and through Pauli's scientific input, a supra-rational, analogical, non-causal structure is admitted back into the conception of nature.

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[162] Jung, *Synchronicity*, 14-19, passim.

[163] As Suzanne Gieser writes, 'Pauli's attitude to astrology was very negative. He could accept the Chinese oracular method I Ching and was open to parapsychological phenomena. But astrology was anathema to him.' Furthermore, he considered Jung's experiments with astrology to be 'unnecessary and … only encouraged a lot of erroneous interpretations by believers in astrology who saw Jung's experiment as support for astrology.' Gieser, *The Innermost Kernel*, 298.

[164] Jung, *Synchronicity*, 43-68.

[165] Ibid., 64-66; cf. Gieser, *The Innermost Kernel*, 285.

[166] E.g. Hanegraaff, *New Age Religion*, 497; cf. idem, *Esotericism and the Academy*, 277-295.

[167] Jung, *The Red Book*.

Synchronicity suggested a program for interpreting nature in ways that resemble the old doctrine of correspondences, allowing for nature to be *read* rather than *measured*. Embedded in the Jungian psychoanalytic process the experience of synchronicity also becomes a key event in what could be seen as a *soteriological* programme – a quest for the purification and transmutation of the soul through the "integration of personality".

Jung and Pauli were certainly not alone in developing a dialogue between modern physics and esoteric thought. We have already seen that quantum physicists of the Copenhagen persuasion did much to forge the foundation of an "emic historiography of science" emphasising a radical break between "classical" and "modern" science, while attempting to build a bridge between modern science and pre- and early-modern natural philosophies, as well as "Eastern" philosophical ideas. But these trends were not exclusive to the Copenhagen school: the 'enthusiastic resignation' and philosophical expansionism was also followed up on by some of the original enemies of the Copenhagen interpretation, arguing the relevance of the field not only for biology, psychology and philosophy, but for religion and mystical though as well. Erwin Schrödinger's later work is a case in point: the Austrian physicist spent the epilogue of his highly influential book, *What Is Life?*, speculating on the problems of free will and consciousness. Referring to the 'great Upanishads' and 'the scholars of Vedanta' Schrödinger was ready to suggest that the identification of the "I" of consciousness with a unitary, single whole, a universal consciousness permeating the universe, was the only logical solution to the apparent discrepancy between the knowledge that the organism is a mechanism, and the undeniable feeling of controlling one's own body and determining one's own actions through will.[168]

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These notable cases lead us to the final conclusion of this chapter: also when it comes to the *substantial* level of developing new areas of esoteric speculation based on modern physical science, the foundation was laid by leading physicists. Some of these conceptual foundations have proved more durable than others: while the modern alchemy discourse of radioactivity largely disappeared after World War Two, the speculative ideas of Pauli, Jordan, and Schrödinger are still very much alive in contemporary

[168] Schrödinger, *What Is Life?*, 88-92, 89. It is significant that Schrödinger ends his epilogue by noting a correspondence between his own view and that of Aldous Huxley in *The Perennial Philosophy*.

"quantum mysticism". However, this observation comes with an important *caveat* that points the direction to later chapters. As Heilbron has noted, after an intense speculative development in the 1920s and early 1930s, the 'assessment of the grander implications of atomic physics passed quickly to philosophers and theologians':[169]

> The immense literature that they created during the 1930s has yet to be surveyed. This much, however, can be said. Few who examined the implications had read Bohr or could tell complementarity from indeterminism. Most obtained their information from the popularizations of Planck and A. S. Eddington, the first opposing and the other promoting the doctrine and consequences of acausality. Where physicists disagree about fundamentals, philosophers may feel safe in their own opinions. [170]

Heilbron made his evaluation in 1985, but not much has happened in the direction of exploring this uncharted territory since.[171] In chapter six I shall make a modest contribution by turning to the question of how popularisers of science, together with scientists and scholars in several fields, continued to co-create a number of "new natural theologies", some of which have become foundational for post-WWII discourses on science, religion, and "mysticism".

[169] Heilbron, 'The Earliest Missionaries', 229-230.

[170] Ibid., 230.

[171] The most notable exception is Peter Bowler, *Reconciling Science and Religion*.