FROM THE FRYING PAN INTO THE FIRE

Cassirer's conception of causality and determinism
and the responses of contemporary physicists

Pim van der Heijden
(Email: heijden.pvd@gmail.com)

Thesis for the graduation in the History and Philosophy of Science, University of Utrecht. (22-12-2014)

Written at the Max Planck Institute for the History of Science, Berlin.

It is somewhat difficult to understand why there should be a tendency of the "collective" to be law-abiding, when the individuals are assumed to rebel, unless one ascribes to the individual a kind of volition to attempt to conform with the law, which is more or less successful according to the rules of trial and error. (Hans Pettersson)

Aber zu einem echten Indeterminismus, der diesen Namen wirklich verdient, käme man erst dann, wenn man sich entschlöße, hier noch einen Schritt weiter zu gehen; wenn man den Angriff statt ihn gegen die Bestimmtheit des Einzelgeschehens zu richten, vielmehr gegen die Bestimmtheit der Gesetze richtete, durch die wir dies Einzelgeschehen beherrscht denken. (Cassirer)

Dagegen schützt sich die Quantentheorie auf dem einfachen Wege, daß sie Gesetze nicht erst angibt; aber ist das ein Schutz? (Laue to Cassirer)

TABLE OF CONTENTS

ABBREVIATIONS OF CASSIRER'S WORKS

SF (1910), *Substanzbegriff und Funktionsbegriff: Untersuchungen öber die Grundfragen der Erkenntniskritik* (Berlin: Bruno Cassirer). Translated by Swabey and Swabey as *Substance and Function & Einstein's Theory of Relativity* (Chigaco: Open Court (1923)).

ET (1921), *Einstein'schen Relativitätstheorie*. (Berlin: Bruno Cassirer). Translated by Swabey and Swabey as *Substance and Function & Einstein's Theory of Relativity* (Chigaco: Open Court (1923)).

DI (1937), *Determinismus und Indeterminismus in der modernen Physik: Historische und systematische Studien zum Kausalproblem* (Göteborg: Högskolas Årsskrift). Translated by O. T. Benfey as: *Determinism and Indeterminism in Modern Physics: Historical and Systematic Studies of the Problem of Causality* (New Haven: Yale University Press (1956)).

ECW *Gesammelte Werke: Hamburger Ausgabe* (Volume 1-26), eds. B. Recki, M. Lukay, T. Berben, R. Schmücker (Hamburg: Felix Meiner (1998-2009)).

ECN *Nachgelassene Manuskripte und Texte* (Volume 1-20), eds. K. C. Köhnke, J. M. Krois, O. Schwemmer (Hamburg: Felix Meiner (1995-2010)).

WORD IN ADVANCE

What follows is a study of Cassirer's philosophy of quantum physics and its reception by some contemporary quantum physicists. Before commencing with my study, I wondered whether any philosopher had been involved in the interpretational issues surrounding the quantum revolutions in the 1920s. To my naïve surprise, the answer was: hardly. This sharply contrasted the situation with Einstein's relativity theory, in which many philosophers publicly interpreted and approved or in some cases even denied the theory. Like Einstein, quantum-physicists like Niels Bohr and Werner Heisenberg dealt with philosophical problems mostly by themselves or in collaboration with other physicists or mathematicians. Positivist philosophers, who were often also trained as physicists or mathematicians, like Philipp Frank, Hans Reichenbach and Moritz Schlick arguably exerted some influence on the physicists' interpretation of quantum mechanics. The more regular German "idealist" philosopher or even the eccentric "*Lebensphilosoph*", in contrast, hardly played a direct part in solving the philosophical challenges posed by quantum physics.

Often, and this was particularly the case with Cassirer and his teachers from the Marburg School of neo-Kantianism, philosophers showed a great concern for a tradition that went back at least a century. Furthermore, their history was deeply intertwined with that of physics. After all, Kant had made important astronomical discoveries. In light of the unity of science, a principle held dearly by many scientists and philosophers alike in an era in which both science, technology and society seemed to gradually fragment and sink into modes of "division" and "exclusion" and eventually, war, I wondered why philosophers were so badly represented in the debates on scientific epistemology resulting from the challenging discoveries brought forward by quantum theory. Were the philosophers too stubborn to consider new physical theories? Did they lack the education necessary to understand the physicists? Were physicists maybe reluctant to discuss their new material with their philosopher colleagues? Or, was there simply not enough time to do both?

Cassirer's *Determinismus und Indeterminismus in der modernen Physik* turned out to be the perfect case study for these general themes. Cassirer seriously studied the results of the newest science and was praised for his understanding, he corresponded with the physicists of his day and had enough time to deal with philosophical issues of for instance culture, language, myth and freedom, and write books on the new physical theories. Although the above questions can hardly be answered in a general sense, Cassirer's case is very revealing. As it gradually became clear to me that the influence of a philosopher like Cassirer on the ideas of physicists at that time were probably marginal, I found that it made much more sense to explore the intellectual relations between these two types of academics and look for the grounds of disagreement or mutual understanding.

1 INTRODUCTION

The following deals with the reception by physicists of a unique book on the historical development of quantum physics written in 1937 by the German philosopher Ernst Cassirer (1874 - 1945). Because of National Socialism, Cassirer had fled to Oxford in 1933 were he lectured for two years. Before arriving in the United States at Yale in 1941, he lectured for six years in Sweden at *Göteborgs Högskola*. Cassirer was both one the most central and respected German philosophers and one of the last man standing in a long tradition of neo-Kantianism.[1] Nowadays, Cassirer is remembered primarily for his philosophy of culture. Yet, he also extensively studied contemporary developments of the exact sciences. Central in his philosophy of science before 1937 are two quite well-known works: *Substanzbegriff und Funktionsbegriff* (1910) and *Zur Einstein'schen Relativitätstheorie* (1921). Less well-known is the work we are here concerned with: *Determinismus und Indeterminismus in der Modernen Physik: Historische und systematische Studien zum Kausalproblem* (1937). In the first decennia of the twentieth century philosophers reflected on the results of the newest science with much eagerness. Concerning the rise of quantum mechanics in the 1920s, however, the situation was wholly different. Besides neo-positivist thinkers, who were often trained as physicists, and the physicists themselves, few other philosophers dared to write on the philosophical implications of this difficult topic.[2] This was still the case in 1937.

The title of Cassirer's book announced that it would address questions about the philosophical meaning and scientific status of causality and the thesis of determinism. These

[1] According to Michael Friedman, Cassirer was "the leading representative of the then dominant neo-Kantian tradition" against which the new traditions of continental philosophy, represented centrally by Heidegger, and of analytic philosophy, represented centrally by Carnap, were defining themselves. (Friedman 2002 p. 264)

[2] In the late nineteenth century and early twentieth century, physicists and mathematicians wrote extensively on the history and philosophy of physics, see for instance the work of: Ernst Mach, Hermann Weyl, Alfred North Whitehead and Victor Fritz Lenzen. This list is far from extensive. Also many philosophers published extensively on physics and were deeply involved in many discussions on statistical mechanics and the theory of relativity. Our main protagonist Cassirer was one of them. The case was wholly different with quantum mechanics. Besides positivist philosophers like Philipp Frank and Hans Reichenbach, at least five non-positivist philosophers published on the exciting but esoteric quantum mechanics in the two decennia before World War II. My suggestion for further research besides Cassirer's *Determinismus*: the work of Émile Meyerson on modern physics, centrally *Réel et déterminisme dans la physique quantique* (1933); the work of Grete Hermann, e.g. 'Die naturphilosophische Grundlagen der Quantenmechanik' (1935) and 'Über die Grundlagen physikalischer Aussagen in den älteren und den modernen Theorien' (1937); Hugo Bergmann's *Der Kampf um das Kausalgesetz in der jüngsten Physik* (1929); Kurt Riezler's *Physics and Reality; Lectures of Aristotle on Modern Physics at an International Congress of Science* (1940); and the debate between Riezler and Ludwik Fleck in their articles titled respectively 'Die Krise der "Wirklichkeit"' (1928) and 'Zur Krise der "Wirklichkeit"' (1929). Greater efforts are required to achieve a comprehensive study of the interrelations between the non-positivists philosophers Cassirer, Meyerson, Hermann, Bergmann and Riezler and, most importantly, the contemporary quantum physicists.

topics were subject to ongoing controversy. The development and success of statistical mechanics had already sparked heavy debates concerning the question whether nature was ultimately deterministic or not. Quantum mechanics allegedly gave the old determinism its final blow. These debates continued up until 1937. Cassirer, who had went in exile because of National Socialism, first in Oxford and then in Gothenburg in Sweden, sent his newly written book to several leading physicists. Among them were Werner Heisenberg and Max von Laue, who were both in Berlin; Max Born, who had fled to Edinburgh; Albert Einstein, who had fled to the United States; and Niels Bohr,[3] who was in Copenhagen. Apart from Einstein, with whom Cassirer had maintained a lively correspondence, Cassirer's relations with these physicists are, as far as I know, unclear. Nonetheless, their few and short responses show that was generally at stake.

More central are three of the reviews of *Determinismus* that appeared in 1937 and 1938. Five appeared in total. One review was written by the German American logical positivist philosopher Ernest Nagel, a well-known German American philosopher of science (*Philosophy of Science* (April 1938)). Another was written by the Italian Hegelian philosopher Carlo Antoni (*Giornale Critico della Filosofia Italiana* (April 1938)). Antoni was an Italian philosopher who was, like his teacher Benedetto Groce, strongly influenced by Hegel. Antoni is known for his book *The Fight against Reason*, which dealt with the historical roots of both German idealism and irrationalism in the struggle against Cartesianism.

As Cassirer had hoped there also appeared reviews were written by physicists. One was written by the young Carl Friedrich von Weizsäcker (*Physikalische Zeitschrift* (1937)), a physicist who in the 1940s worked with Heisenberg Berlin.[4] Weizsäcker would later also become known as a philosopher. An extensive review was written by Philipp Frank (*Theoria* (1938)), physicist and a member of the *Wiener Kreis*, who was at that time in Prague.[5] Frank was also a positivist philosopher. Another review was written by Hans Pettersson (*Theoria* (August 1937)), who had studied in Vienna and had contact with Cassirer in Gothenburg (Sweden)—were Cassirer wrote *Determinismus*. Pettersson was an atomic physicist and oceanographer who in 1935 grounded the Institute for Oceanography in Gothenburg. Pettersson was philosophically interested and Cassirer gave a lecture at his institute on Kant and modern biology in 1940.[6] Later in his life Pettersson became a member of the Royal Society. These three responses are very revealing and show what was generally at stake and what was thus expected of Cassirer as a well-established neo-Kantian philosopher writing on the explosive topic.

---

[3] It is unclear whether it ever arrived, let alone if Bohr read it. See: http://agora.sub.uni-hamburg.de/subcass/digbib/ssearch (visited on: 26-11-2014).

[4] At that time Weizsäcker worked on the nuclear processes of stars. He published several articles on his theoretical findings at a very young age. Shortly thereafter in 1939 he became Heisenberg's protégé in the Germam *Uranprojekt*, set out to produce a nuclear weapon.

[5] Frank later became lecturer in mathematics and physics at Harvard University. Although Frank was also influential as a philosopher, in the present study he will be presented mainly as a physicist. As it will turn out, Frank shared much of the worries about Cassirer's treatment of causality with the other physicist commentators.

[6] ECW 18: p. 313.

Rather than defending Cassirer in retrospect, I will focus on his philosophy in order to explore the interrelations with his physicist correspondents and reviewers. On the one hand, the book was well received. The correspondents and reviewers generally agreed with Cassirer's exposition of quantum mechanics the relevant historical developments. On the other hand, there also was much uncertainty with regards to what Cassirer was actually defending with respect to the status of the concept of causality and the thesis of determinism, which was after all the book's main topic. In general, we can say that Cassirer did not take a stance toward the question that his physicist audience was expecting. Moreover, because of Cassirer's move toward a more general synthesis of the various competing positions with respect to causality, his readers sometimes doubted whether he was defending a determinate position at all.

In a way, Cassirer's incorporation of several conflicting positions into a more generalized position circumvented difficulties which were of the utmost importance to contemporary scientists. For that reason, *Determinismus*' historical content was in some cases better appreciated than its philosophical content. Notwithstanding these issues, I will also make clear that why albeit important disagreements, Cassirer's book had taken into account the demand of the physicists to consider some of the surprising or even revolutionary implications of quantum mechanics. His book did so by disagreeing with Kant and defending a notion of a "not entirely determinate physical state", a description that allows that not all physical properties simultaneously have a precisely defined value.

Of all the preserved responses to *Determinismus*, only Weizsäcker recognized that the essential philosophical problem of quantum mechanics was for Cassirer not so much the Kantian category of "cause and effect" but rather the category of "thing and property", or the category of "substance and accident".[7] These categories, Cassirer had defended already in 1910, were entirely senseless in order to understand the philosophical implications of the newest science. The workings of theoretical reason (*Theoretische Vernunft*) as laid down by Kant had to be modified and the traditional concepts had to be supplemented with the concepts of "function" and "structure". However, this more fundamental argument was at times clouded by Cassirer's apparent unorthodox position on the problem of causality.

Part I treats the philosophical climate in which Cassirer developed his ideas, Cassirer's philosophy of function, Cassirer's encounter with relativity theory and some issues with Kantianism expressed by physicists reviewers of *Determinismus* and Cassirer's correspondents. Part II treats Cassirer's thoughts and the physicists' responses on causality and determinism. Finally, I will discuss why Cassirer wrote on the topic of quantum mechanics at all. Undoubtedly, Cassirer felt that as the existing debates surrounding quantum mechanics fuelled the for him unacceptable view of indeterminism, there were important theoretical concepts at stake. Besides this being centrally an epistemological motive, I will also explore how this question relates to the last chapter of *Determinismus*, a chapter devoted to freedom and autonomy. Even though Cassirer concluded that there is no relation between quantum mechanics and ethics, it becomes clear that Cassirer favoured causality and in a sense also determinism partly for reasons connected to the Kantian practical reason (*Praktische Vernunft*).

[7] Weizsäcker 1937.

1.1 Unfavourable pre-conditions

Determinismus placed the development of quantum mechanics within an extensive intellectual history from Heraclitus to Heisenberg and forwarded its philosophical novelties in relation to more than two millennia of philosophical history. In the Schilpp edition on Cassirer in the Library of Living Philosophers,[8] Dimitry Gawronsky has noted that Cassirer himself regarded *Determinismus und Indeterminismus* as one of his most important books.[9] Felix Kaufmann remarked, in the same edition, that Cassirer's *Determinismus* was at that time perhaps the most complete critical representation of quantum mechanics.[10] A study of the reception of Cassirer's writings on physics is also worthwhile in light of the recent revival of his philosophy of science.[11] Also, *Determinismus* plays an important role in some discussions on structural realism and the possibility of a realistic foundation of physics.[12] Although here we will not pursuit such goals, it should be taken into account that *Determinismus* was by no means a nine days' wonder.

Nonetheless, it is safe to say that Cassirer's *Determinusmus* has been largely overlooked by academic philosophers, historians and physicists alike. This is remarkable because Cassirer received many compliments his extensive and convincing historical overview and sharp remarks, which will be discussed in part II. Cassirer argued against a more classical and also Kantian position that we must see physical states as being "not entirely determinate". Instead of opting for a thorough indeterminism, he thereby nevertheless took into account what was regarded as the most central revelation of quantum mechanics, namely a drastic infringement of determinism. Therefore, there seems to have been much ground for mutual understanding, namely the mutual recognition that a more or less Kantian assumption of a complete and general determination of physical reality must be rejected. Yet, of the physicists, only Weizsäcker explicitly mentioned Cassirer's claim.

Also crucial is that earlier, in the decennia before the developments that lead to the theory of quantum mechanics, there had been much resistance to theories of relativity stemming from deep within Kantian or neo-Kantian philosophy. Objections were raised against relativity, centrally to Einstein's, both on grounds of how science ought to function and concerning the theory its implication for metaphysics or epistemology. As is well known, relativity theory revealed to be too big of an opponent for the objections stemming from within the somewhat orthodox Kantian philosophy science, that is, it did not succeed in rejecting the theory. A more viable option was, however, to immunize Kant's transcendental psychology from threats posed by relativity theories, defending roughly that scientific theories could not affect the contents of Kantian philosophy. Klaus Hentschel calls this an "immunization

[8] Published in the same year as the edition on Einstein (1949).

[9] Gawronsky 1949 p. 29.

[10] Felix Kaufmann 1949 p. 127.

[11] See for instance: Ferrari 2009; Friedman 2000, 2005, 2008; Heis 2010, 2012, forthcoming a, forthcoming b; Ihmig 2001; Meland 2010; Mills 2014; Mormann forthcoming; Neuber 2012; Pringe 2014; Schmitz-Rigal 2002.

[12] A few examples are Gower 2010, Schmitz-Rigal 2009 and Cei & French 2009.

strategy".[13] Since both strategies eventually drew the short straw, these defence mechanisms significantly harmed the status of neo-Kantian projects as a whole. As we will see, the pre-history with relativity probably affected the reception of Cassirer's *Determinismus*.

Yet another neo-Kantian response was possible. This option is often said to have been the most viable and long-lived.[14] Cassirer neither rejected relativity theory, nor did he attempt to immunize Kant's system against it. Considerable steps were undertaken by him and other neo-Kantians, like Paul Natorp and Hermann Cohen, to take over Kant's method of philosophizing and work in the "spirit of Kant" and at that the same time allow for alterations in Kant's system. This is why neo-Kantian philosophies like Cassirer have been called "revisionist".[15] Indeed, the stage was set to depart from Kant's transcendental psychology. Yet, the term "revisionism" captures only half of Cassirer's attitude toward Kant. It misses his insistence that although principles like space, time and causality have to be adapted to contemporary scientific findings, epistemology nevertheless aims to establish principles which are universal, necessary and absolute. The true a priori of science remained for Cassirer to be synthetic and non-empirical.

Quantum mechanics showed that the Newtonian laws of motion could no longer be seen as necessary conditions for the possibility of experience of moving material bodies. Yet, that Newton's laws turned out to be impermanent did not mean that the Kantian explorations were entirely useless. Kant has shown that given a particular way of conceptualizing the phenomena, namely Newtonian mechanics, it is necessary to adopt certain a priori principles, like those of Euclidean geometry, absolute time and a continuous causality. As Philip Kitcher (1996) has put it, we might therefore even conclude with respect the status of Newtonian mechanics that Kant's arguments did "not transform its epistemic status", rather they added to the "credibility of the theory."[16] In order to demonstrate the indispensability of particular concepts we must turn to a specific way of conceptualizing and this means that the a priori principles are in a way "vulnerable" to experience and scientific knowledge.

Although logical positivist philosophers often started out as neo-Kantians, as German philosophy was deeply Kantian at that time, most of them attempted to abandon the Kantian camp. Like Cassirer, logical positivists as Moritz Schlick defended that *all* knowledge is corrigible. Schlick, however, had very different reason for saying this was so. Schlick argued that Cassirer's treatment of relativity theory in 1921 was lacking because Cassirer had defended absolute a priori principles incapable of refutation by scientific experience.[17] For these reasons, it appears that by the time that *Determinismus* was published, neo-Kantianism had lost its previous high standing status in debating the philosophical problems posed by the newest

---

[13] See: Hentschel's *Interpretationen und Fehlinterpretationen der speziellen und der allgemeinen Relativitätstheorie durch Zeitgenossen Albert Einsteins* (1990).

[14] For instance by Matthias Neuber (2012) and Hentschel (1990).

[15] This is used for instance by Neuber, who's book is entitled *Die Grenzen des Revisionismus, Schlick, Cassirer und das "Raumproblem"* (2012). Also Hentschel says that Cassirer's philosophy belongs to the category of *Revisionsstrategie*. (e.g. Hentschel 1990 p. 232)

[16] Kitcher 1996 p. 410. Kitcher concluded this in a review of Michael Friedman's *Kant and the Exact Sciences* (1992).

[17] See: Schlick 1921.

physics. This, I believe, partly explains why the book has always played such a peripheral role in comparison with for instance *An Essay on Man* (1944) and his *Philosophy of Symbolic Forms* (1923-1929). In a way, history repeated itself in 1937 and Cassirer's correspondents and reviewers had either already taken their stance in the 1920s or showed a strong lenience toward a position similar to Schlick's in 1921.

PART I

PHILOSOPHICAL AND HISTORICAL CONTEXT

2 CASSIRER'S CONFESSION

2.1 A confession

Cassirer's foreword to *Determinismus* started off with a confession, namely that a personal motive had led him to write the book. He felt that physics and philosophy were asking similar questions and that physicists and philosophers could therefore not continue to work silently alongside each other, ignoring each other's work. The situation was somewhat similar to that of *Substanzbegriff und Funktionsbegriff* in 1910 when Cassirer already expressed a deep concern for the epistemological significance of modern logics, mathematics and physics. Both books, as Cassirer pointed out in his foreword to *Determinismus*, sought to "disclose a unified methodological tendency" within the history of science, one from the concept of substance toward the concept of function. (DI: p. xxi)[18] This tendency, Cassirer expressed, could by no means remain an affair strictly of the mathematical and natural sciences. With the arrival of quantum mechanics the matter of an epistemological analysis of the results of science had become extremely pressing:

> *No account was taken of the powerful and dangerous 'explosive' of quantum theory, as Planck once called it. But now that the effects of this explosive are becoming increasingly evident and extend over the whole field of physics, it becomes more and more imperative to investigate their historical origins and their systematic foundations. The first notes for this book were made in the desire to fulfil this demand. Initially they were not intended for publication but solely for clarifying my own viewpoint* [Selbstbelehrung] *and for the critical testing of the basic epistemological thesis from which I had started.* (DI p. vi: p. xxi-xxii)

Cassirer explained why he nevertheless decided to write a book on the basis of what until then had merely been personal notes. Quantum mechanics is still "*in statu nascendi*" concerning the fixation of its fundamental concepts (*Grundbegriffe*). Therefore, Cassirer said, it would profit from making ground for a "common inquiry" (*gemeinsame Forschungsarbeit*) of physics and philosophy. (DI p. vii: p. xxii)

Likewise, in the preface to his essay on Einstein's relativity theory, *Zur Einstein'schen Relativitätstheorie* (ET) (1921), Cassirer had already expressed earnestly that he did not claim to present a complete account of the philosophical problems of relativity theory. Aiming nevertheless to fully understand the theory Cassirer contacted Albert Einstein and sent him his manuscript. Einstein complemented Cassirer with his understanding of physics which was rare, Einstein said, especially for a philosopher. (ECN 18: 16-6-1920, 15-7-1920, 28-8-1920)[19] Considering that the opinions of physicists and philosophers were still widely spread, Cassirer

[18] The references to *Determinismus und Indeterminismus in der Modernen Physik* (DI) will often include both a page number of the original German edition and of the English translation (e.g. DI p. 126: p. 103). References to the English edition only appear as e.g. DI: p. 16.

[19] Dates refer to the selected and published scientific correspondence in ECN 18.

said, the purpose of his essay was not per se to establish a final interpretation, rather the essay would succeed if it prepared the ground "for a mutual understanding". (ET p. 349) (ECN 18: 10-5-1920)

Enthralled by the theory, Cassirer gave a course on the philosophical problems of theories of relativity as a professor at the University of Hamburg in the period leading up to the publication of *Determinismus*.[20] Many philosophers had written on the philosophical problems arising from relativity. The situation with quantum mechanics, however, appears to have been much less compelling for philosophers to publish. The call for a philosopher like Cassirer to write on quantum mechanics twenty-five years after his essay on relativity was therefore perhaps even stronger. In any case, Cassirer's foreword to *Determinismus* confirmed that his motivation to write also on this theory was once again the possibility of lively dialogue. (DI: p. xxii)

2.2 Philosophy of science

Also when reading Cassirer's correspondence it becomes clear that what was at stake was far more than the right interpretation of modern physics. In 1931, Hans Reichenbach, who had studied with Cassirer in Berlin, wrote Cassirer that the time had come for the German government to create a chair in the "philosophy of nature" or "natural philosophy", similar to what we today call philosophy of science. Reichenbach had set up a petition and achieved to have it signed by David Hilbert, Albert Einstein, Heinrich Göbel, the inventor famous for his claim of the invention of the light bulb, and Carl Bosch, founder of IG Farben and Nobel laureate in chemistry. Reichenbach shortly thereafter informs Cassirer that he had been the only philosopher to sign the petition. The animosity of natural scientists against the trend in philosophy to incorporate the results of contemporary science was widespread and deeply rooted, Reichenbach wrote. He said that the project would therefore greatly benefit from the approval of somebody with a status like Cassirer. (ECN 18: 15-6-1931) Cassirer's earlier response to the petition had made clear that the matter of creating a chair was as urgent as it was delicate. However, Cassirer wrote, philosophers might unnecessarily experience competition and feel threatened by the idea of a future shift of attention toward the natural sciences, away from the common *geisteswissenschaftlichen* and *geistesgeschichtlichen* methods. (ECN 18: 11-6-1931)

Although clearly forming a minority, Reichenbach and Cassirer stood not alone. Schlick had also been a strong defender of a "scientific philosophy". Much later in 1941, also Weizsäcker complained of the increasingly becoming bigger gap between the different sciences and particularly between the natural sciences and the *Geisteswissenschaften*.[21] Moreover, he explicitly stated the necessity of a cooperation between physics and philosophy.[22] Also Pettersson noted to have enthusiastically informed Cassirer about his interests to establish a

---

[20] ECN 8 pp. 31-49.

[21] Weizsäcker 1941 p. 185. At that time, in a Germany at war ruled by national socialists, Weizsäcker performed nuclear research under Heisenberg's leadership. There is ongoing debate about whether he and the other members of the "Uranium Club" intentionally cooperated on the project to construct a nuclear bomb.

[22] Weizsäcker 1941 p. 194.

cooperation between philosophy and science in 1945.[23] Apparently, the case for a philosophy of science was as urgent as it was difficult. With *Determinismus,* ground could have been gained for a neo-Kantian philosophy of science. Yet, the conclusions of philosophically minded physicists and some logical positivist philosophers were much longer-lived.

2.3 Publicity

Right after publishing *Determinismus*, Cassirer wrote Reichenbach and said that he would love to see *Determinismus* reviewed.[24] A review would mean more readers, and give it at least some attention, Cassirer reasoned. It would particularly be good, he said, when it would be reviewed by a physicist:

> *Es wäre schönn, wenn Sie für die* Erkenntnis *einen guten Referenten (vielleciht einen der maßgebenden Physiker) gewinnen könnten, damit das Buch auch in dem deutschen Leserkreis einigermassen bekannt wird—an eine Besprechung in anderen deutschen Zeitschriften ist ja nicht zu denken.* (ECN 18: 1-9-1936)

Reichenbach proposed to ask Ernst Aster or Erwin Schrödinger.[25]An obvious choice for the review would be a member of the *Wiener Kreis*—or what was left of it after its founder Schlick had suddenly been assassinated the year before. A member of the Vienna Circle, however, would not be preferable since Cassirer's thoughts differed too much from theirs, Reichenbach responded.[26] (ECN 18: 10-3-1937) After Schlick's death, the anti-semitical rethoric would generally harden, even though Schlick himself was not Jewish. It was said that relativity and quantum mechanics had to be banned because these theories had a distinctive Jewish character. Cassirer referred to the debates around the problematic debated about the matter of "*deutsche und jüdische Physik*" and noted that since academic life in Germany was put under heavy constraints during National Socialism and many academics were losing their positions, it was

[23] There is no paper trail of this correspondence. In a letter to the Hungarian mathematician Marcel Riesz he admitted that he did not find this an easy task. He noted that he had to strain his brain in order "to find a possibility to raise a discussion on these points" and regarded his attempt to arouse the interest of both philosophers and scientists as "unfortunate" and "regrettable". Pettersson wrote this to Marcel Riesz in 1945. (Peetre, Jaak & Magnusson, Rooney (Eds.) 2009 p. 61-62)

[24] At that time, Reichenbach was head of the Departement of Philosophy of the University of Istanbul and founder of the "Berliner circle", i.e. the *Gesellschaft für empirische Philosophie*.

[25] It is unclear whether any of the reviews of *Determinismus* were established with the help Reichenbach.

[26] Interestingly, we also learn from the correspondence with Reichenbach that an article called "Kritik der Wiener Schule" in which Cassirer systematically attacked the positivist-enterprise written for *Erkenntnis* in 1929 was not published as with Schlick's passing it had become senseless to attack what was more or less "his" school of thought. Eventually, however, about ten years later, parts of the article appeared in various publications. For instance in "Ziele und Wege der Wirklichkeitserkenntnis". (See: ECN 18: endnote 314) This marks the emphatic intellectual relation between Schlick and Cassirer, despite their heavy rhetoric in the relativity debate.

clear that not everybody's work was welcome.[27] Cassirer probably expected that therefore it would be difficult to get a review in journals other than the *Erkenntnis*, which was co-founded by his friend Reichenbach.

Notwithstanding his request, a review of *Determinismus* in *Erkenntnis* never appeared and his book appears to have remained silently in the background of the heated debates on causality.[28] But luckily, a review of *Determinismus* written by Weizsäcker did appear shortly after its publication in *Physikalische Zeitschrift*. It was probably a happy surprise for Cassirer to see that this review was published in an important physical journal, because this meant the possibility of having a lively dialogue between physicists and philosophers. Four more reviews followed suit. To an important extent, Cassirer achieved his goals. He received comments in letters from physicists to whom he had sent the book. As far as it is known, Cassirer received responses from Einstein, Laue, Born, Heisenberg and Frank.[29] Moreover, the work was reviewed on four more occasions, by the physicists Pettersson, Frank and the philosophers Nagel and Antoni.

---

[27] Cassirer remarked that Laue's and Heisenberg's positions were at stake. (ECN 18: 1-9-1936)

[28] Only years later there appeared entry in *Erkenntnis* (1939) solely stating its title and its author. See: Anonymous 1939.

[29] It is not clear whether Bohr ever read the book. See the response of Bohr's secretary while he was away in America: http://agora.sub.uni-hamburg.de/subcass/digbib/ssearch (visited on: 26-11-2014).

3 PHILOSOPHICAL CLIMATE

3.1 Objectivity

Cassirer's views on science are partially retraceable to a form of objectivity that emerged the late nineteenth century. For that reason, it is worthwhile to dwell for a moment on this view on objectivity. In the astonishing work of historical epistemology entitled *Objectivity* (2007) Lorraine Daston and Peter Galison claim that proponents of the epistemological goal of objectivtiy, and in particular, proponents of what they call "structural objectivity", were found in logic, mathematics, physics and philosophy.[30] One important factor in the emergence of structural objectivity as a scientist's holy grail, according to Daston and Galison, was the experience of an ineradicable psychological, political and historical diversity of an ever-growing world. Accordingly, scientific knowledge was rapidly becoming more complex and the hope was set to establish universal invariant relations.[31]

This aim for universal invariants was partially retraceable back to Kant. In the *Kritik der reinen Vernunft* Kant had preserved the adjective "objective" for his universal and a priori conditions of experience. The objective was not identified with by the ultimate nature of things in themselves but with something that had to do with the faculty of understanding and with pure thought. The "subjective", in contrast, was identified with the "empirical" and with sensations.[32] As a reliable source of knowledge, sensation and intuition were highly distrusted as they were bound to the individual and very likely to vary. Some even rejected them completely.

Like Kant, scientists and philosophers found common ground in their animosity against subjectivity. Opposed to forms of enlightenment sensationalism scholars and scientists in search of objectivity challenged the claim of the permanence of intuitions. There was something about intuitions that made them seem independent, out of control. It would be most subjective to believe that pure "helter skelter" sense impressions were enough for the establishment of knowledge. In contrast, it was thought that concepts keep each other in check and allow us to be critical. Moreover, the mind was not a *tabula rasa*, as sensationalists like John Stuart Mill and John Locke had typically claimed. With the mid-nineteenth-century appropriation of the Kantian terminology of objective and subjective, the focus of much science shifted from metaphysical truth to objectivity as a new and distinct epistemological goal, Daston and Galison argue.

In several important ways Cassirer was very much a child of the "structuralist fever" that extended even to the 1910s and 1920s.[33] It is noted in *Objectivity* that Cassirer was aware

---

[30] Daston & Galison 2007 p. 254. Thoughout their chapter the philosophies of Frege, Poincaré and Carnap serve as paradigms of structural objectivity as they are shown to have certain fundamental commonalites. Also Peirce, Russell, Planck and Schlick are said to have spoken out for structural objectivity. Even Einstein's view of objectivity is partly structural.

[31] Daston & Galison 2007 pp. 256-262.

[32] Daston & Galison 2007 pp. 209-210.

[33] Daston & Galison 2007 p. 256.

of the development and understood it as a tendency that was correlated with the modern advances of the natural and mathematical sciences.[34] Compared to the abstract schemata of logic, mathematics and physics, he said, sensations express "only a subjective state of the observer."[35] (SF p. 275) The ideal of physics seems to have reached its conclusion with relativity, Cassirer wrote in 1921, since "all sensuous and intuitive heterogeneity has passed into pure homogeneity." (ET p. 448) "The sensuous immediacy and particularity of the particular perceptual qualities are excluded, but this exclusion is possible only through the concepts of space and time, number and magnitude." (ET p. 445) As a result, he said: "No individual form can grasp its absolute 'reality' as such and give it complete and adequate expression." (ET p. 446) This outlook on scientific knowledge implied that the scientists show a great deal of self-restraint, as scientists must continuously resist the temptation to believe in their intuitive views of the world. Proponents of structural objectivity held that what is shared is unlikely to vary and can therefore reasonably be called objective. Contrary to the sensationalists believe about the constancy of sensory impressions for individual observers, they held, like Cassirer, that objectivity lay not in the observable facts but in invariant structures. Cassirer notes at various instances how this focus on invariant structures unites critical idealism and positivism.[36]

Crucial for objectivity was what Kant had called "communicability" (*Mittheilbarkeit*).[37] The possibility of communication of a judgement served both as criterion and motivation for objectivity, just as Kant had sought knowledge that would be valid even for angels. If rational beings can communicate a judgement to each other, then there is solid ground for the presumption that they take part in the same objective judgements. A completely objective judgement for Kant then, can be construed as a judgement that somehow universally takes part in a "shared reason" or a "shared world".[38] Similarly, Cassirer argued that in the background of all the contemporary and historical disagreement among physicists lies an "inner constancy, an immanent methodological coherence" in which we "may perhaps expect and hope to discover certain basic principles which are invariant with respect to the different epistemological systems of reference." (DI: p. 30) As Cassirer expressed in a letter to Moritz Schlick, an a priori idea is not a "mere convention" (*blosse Konvention*) but an expression of "reason, of *logos* itself." (ECN 18: 23-10-1920)

3.2 Kantianism and the Marburg School

Cassirer was affiliated with a group of philosophers that were called the Marburg School of neo-Kantianism.[39] In Marburg, Cassirer studied with its founders Hermann Cohen and Paul

[34] Daston & Galison 2007 p. 260.

[35] See in the original German edition: SF pp. 322, 324, 361.

[36] See for instance: ET p. 427.

[37] Kant 1998 A820/B848.

[38] Daston & Galison 2007 p. 262

[39] Besides the Marburg School, another known school was the Baden or Southwest School of neo-Kantianism, occupied with logic and epistemology but also particularly with culture, ethics and theology. This school was led by Heinrich Rickert. In addition there was also a more Friesian current

Natorp. Although gradually becoming more and more fragmented toward the thirties, Cassirer would take over a great part of both the methodology and the concerns of his teachers. The aims and interests of the Marburg School can be summarized by discussing shortly two distinct characteristics. The first characteristic explains both the general aim and procedure of the Marburg School and shall therefore be discussed somewhat lengthier than the latter.

3.2.1 *The "fact" of science*

Cohen and Natorp famously interpreted Kant as providing a theory of scientific knowledge, that is, as an epistemologist (*Erkenntniskritiker*). In the 1870s Cohen had started laying down the principles of Kant's "transcendental method" in a novel way and took this method as the principal dictum of his philosophical approach. Cohen and Natorp endorsed a way of philosophizing that started with the "fact" of empirical science, *simply* taking for granted the truth of the laws and relations put forward by contemporary science. Contrary to normatively laying down universal foundations for empirical science, the Marburgians attempted to clarify objectivity on the grounds of current contemporary developments. This procedure allowed thought to inquire into the "genesis" of knowledge.

It was believed that Kant's system of categories had to be thoroughly altered in light of the rapidly progressing theoretical sciences. Modern developments in the exact sciences would increasingly raise questions that could not be answered by these sciences alone. And as Cassirer even defended in 1937 concerning quantum mechanics, scientific results somehow pointed back toward their own philosophical foundations. It would become an increasingly pressing matter to ask questions about the various conditions that enable the variety of scientific endeavours. By asking how theories can be possible at all, philosophical insight into the universal meaning of all kinds of crucial notions might be attained. In doing so, they would go into the theories "substantively", asking if theories were actually true or not, or if and how they corresponded with reality. In this respect, Cassirer therefore opposed "his" procedure of searching for the basic invariant principles that regulate the contingent formation of physical concepts with what he called "theories *about* physics". (DI: p. 30) Like Kant had stressed, it was not that fundamental concepts like causality, existence, object, and also space and time, were to be understood as the fundamental building blocks of reality. Instead, such concepts were argued to be absolutely necessary for the possibility of experience. As such, a priori concepts do in this sense not possess any truth, rather they were considered to be objectively valid.[40]

Central in Cohen's methodological commitment to Kant was his revision of Kant's original doctrine of the unknowable thing in itself (*Ding an sich*). On the one hand, Cohen explicated that *Dinge an sich* do not have a strictly negative meaning, designating only *that* we do not know things as they are in themselves and merely now things as they appear in interaction with the senses and the categories of the understanding. On the other hand, Cohen did not understand them either as positively designating what is called a "*noumenal*" world,

---

This school was inspired by the interpretations of Kant's works provided by Johann Jacob Fries in the early nineteenth century and was represented by Leonard Nelson.

[40] Kant 1998 A20-30/B37-45, A96-97.

that is, a realm of objects that exists independently of our representations that is presupposed to ultimately give rise to our sensations.[41] Cohen argued instead that the thing in itself must be seen as the perfect totality of all experience and knowledge. It is exactly this perfect totality that science continuously aims for but can never completely attain, Cohen said. As Kant had already said, "[s]ystematic unity (as mere) idea is, however, only a *projective* unity, which one must regard not as given in itself, but only as a problem."[42] For this reason science is intrinsically idealistic and Cohen named this the "genetic conception of knowledge".[43] Cassirer took over this fundamental idealistic tendency of thought toward a perfect totality as he continuously laid emphasis on "the fact that the road continues farther and farther ahead" and said: "and that we see no end, no *non plus ultra*, need not trouble us, for the truth which we seek, being an empirical truth, can only be that of a process and not of a finally concluded result." (DI: p. 150)

Like Cohen, Cassirer emphasized this idealistic process as a "productive synthesis", a term originating from Kant.[44] In this process, thought continuously sets itself the task of reality. Reality, as Cohen saw it, is simply the endpoint toward which the mathematical structures of knowledge are endlessly converging. But as the theories change, the real endpoints change with them. Cassirer was deeply inspired by this reading of Kant, and occasionally repeated Cohen's vision: "This goal may never be completely attained at any given stage of knowledge; nevertheless, it remains as a *demand* and determines a fixed direction in the continual unfolding and development of the system of experience itself".[45] (SF p. 267) Cassirer also took over Cohen's idea that with every new stadium of science, new particular scientific object are hypostasized.[46]

In *Determinismus und Indeterminismus* Cassirer provided an example that explains this productive and synthetic strive for unity with respect to physics. The striving toward perfect unity was most clearly visible in physics were all its major departments; mechanics, chemistry, thermodynamics, and electrodynamics work toward the common goal of a definite

---

[41] Already in Kant's day, a common objection to his thing in itself was that if it is thought to transcendentally give rise to sensations, it is not clear why things in themselves are nevertheless not in space and time and not causally related to us. The idea that the thing as it is itself affects us is then incoherent and the concept collapses. (See footnote 78)

[42] Kant 1998 A647/B675. (See also footnotes 90, 302, 303 and 373) Cohen wrote in his preface to *Begründung der Ethik* (1907): "Aber die Dinge sind uns nicht gegeben, sondern aufgegeben." Cohen also spoke of the task in the sense of a riddle. See: Cohen 1871 p. 3. The philosopher of Baden school of neo-Kantiansim Heinrich Rickert, in *Der Gegenstand der Erkenntnis* (1921), also defined the object of transcendental idealism in these terms: "For the transcendental idealist, the object of knowledge is … neither immanent nor transcendentally 'given' [*gegeben*], but rather 'set as a task' [*aufgegeben*]". Another who noted the "task-like character of reality" was the student of Hilbert, Hermann Weyl in *Philosophie der Mathematik und Naturwissenschaft* (1927). (References in: Ryckman 2014 p. 397 (footnote 21))

[43] For Cohen's articulation of the philosophical principles of Marburg neo-Kantianism see: Cohen 1871 and Cohen 1883.

[44] See for instance: Kant 1998 A116, A410. See also: Coffa 1991 pt. I.

[45] Original German edition: SF p. 357.

[46] See also: Felix Kaufmann 1949 p. 130.

"structure" or "form" (*Gestalt*) of the atom. The problems and paradoxes arising in relation to the problem of atomism and the goal or hope to achieve a coherent solution was seen by him as one of the key motivations for thought to engage in theoretical science at all. (DI p. 237: p. 190)

3.2.2 Syntheticity

But what had Kant understood by syntheticity? "Pure concepts" like the *Dinge an sich*, Kant had said, were provided by the faculty of "transcendental imagination". Kant tirelessly defended that some ideas, like causality, existence, space and time are transcendental because they are not found within experience. They are not reducible to the simple categorization of objects as they are found within the world of appearances, or, in an Aristotelean sense, to groupings on the basis of the shared properties of objects. Such ideas must therefore be a priori. In contrast with a posteriori empirical ideas which are contingent, the pure concept of existence is universal and therefore necessary. It appears earlier in the construction of knowledge, so to speak.

More importantly even was that Kant famously proclaimed that the most interesting a priori ideas are "synthetic", as opposed to "analytic". In contrast with analytic knowledge, synthetic a priori ideas cannot be reduced to trivial matters of definition. Because, in contrast with analytic judgements, the conclusion is not contained within the premises, some "activity" of thought must take place order to attain synthetic a priori knowledge.[47] It was precisely this syntheticity that formed the core of Kant's "general problem of pure reason".[48] The question as to how synthetic a priori judgements are possible gave rise to much debate, even up until Cassirer's day as we will see particularly below in chapter 5.

The epistemological principles Cassirer was concerned with in his historical and philosophical analysis of quantum mechanics were understood to display precisely such a synthetic character. The categories specifically on Cassirer's agenda in *Determinismus* were "cause and effect" and "substance and accident". Even the category of the "free will" was discussed in his last chapter. Clearly, these ideas are not simply found within experience, that is, they are not *a posteriori*. Nor can we derive them by abstracting from the "normal" concepts that designate the things in our everyday world. We can also not base them on apodictic definitions. Thus, Kantians concluded, at least some mediative activity of thought must come into play. At least some productive activity of reason must be presupposed. That means that a posteriori representations are essentially constructed with the aid of synthetic a priori knowledge.

3.2.3 Intuitions

The **Fehler! Textmarke nicht definiert.**Marburg School of neo-Kantianism showed to be taking part in the much broader historical trend of the rejection of intuitions as a reliable source of scientific knowledge. The "current best" physical theory for Kant had been Newtonian

[47] Kant's famous example is "*7+5=12*": The concept "*12*" is not contained in the concepts "*7*", "*5*" and "+": Kant 1998 A37-39/B14-17.

[48] Kant 1998 B19.

physics. With respect to Newton's mechanics, problems with intuition did not arise as heavily as they did with arrival of relativity theory and quantum mechanics during the first half of the twentieth century. Besides the mysterious concept of action-at-a-distance that Newton introduced, Newton's mechanics seems to fuse relatively well with the perceptual world. For Kant it was therefore much less of a problem to see intuition (*Anschauung*) and the senses as a faculty that was clearly separated from the concept (*Begriff*) and the faculty of the understanding. Cohen and Natorp found that the dependency of the faculties of sensibility and understanding roughly meant for Kant that the traditional forms of judgement supplied by Aristotelean formal logic were wholly distinct from pure mathematics, seen as a reflection of the pure intuitions of space and time.[49]

In light of the results of modern exact science, however, the old Kantian notion of representations as the intersection of intuitions, supplied by the senses, and concepts, supplied by the understanding, was in deep need of revision. How these faculties nonetheless relate and allow us to establish coherent representations was a fundamental problem for which we should look at what Kant called the "transcendental schematism of the imagination". In this mediating process, Kant held, categories are "schematized" in terms of intuition. Instances of such schematizations are the category of "substance" and the category of "causality" which are respectively connected with the temporal representations of respectively "permanence" and "succession". However, the Marburgians generally observed that theories increasingly showed a "discursive" character. As we will see in part II, quantum mechanics showed for Cassirer that the pure concept of causality attained a more independent status as it could no longer be directly coupled with the "succession" of events in a continuous time.

The fundamental structure of the intellect is based on procedural rules instead of direct representations of nature. That reason proceeds by a certain rule was seen clearly in for instance the modern mathematical concepts of function, relation and series. Concepts are not simply applied to intuitions in order to make sense of them, Cohen and Natorp found. Rather, intuition is thoroughly shaped by conceptual thought and the a priori must therefore be based upon the faculty of understanding alone. Generally, this development was in line with Kant when he had said that particular objects are not simply given in intuition, but that it is in the concept where the manifold of intuition is united.[50] In Kant, the sensibilities were already seen as an essentially passive, affective and receptive faculty. It produces essentially heteronomous results, whereas thinking is more reliable as it is primarily active and spontaneous, or simply autonomous.[51] The Marburgians radicalized this approach by rejecting the possibility of independent intuitions.[52] Instead of agreeing with Kant that representations arise through the application of concepts to the objects supplied by intuitions in the framework of space and time, Cohen envisioned that it would corrupt knowledge with subjectivity to assume that there are primarily unmediated impressions given to the mind, already even before coherent

[49] See for instance: Friedman 2002 p. 265-266.
[50] Kant 1998 B137. See also: Kant 1783 §19 and Cassirer 1929 pp. 4-5.
[51] Kant 1998 A68/B93.
[52] See also: Lydia Patton 2005.

representations arise.[53] Cassirer would say that it is the "rule of the understanding" alone through which appearances can acquire synthetic unity and can be taken together as a whole in a determinate concept of experience.[54] (ET p. 415)

Instead of being indebted directly to the senses, Cohen held, theoretical comprehension gradually becomes established in accordance with the norms and criteria immanent in thinking. Intuition appeared to be completely superfluous, as Cassirer expressed it in 1937:

> [*W*]*e can no longer seek this specification in the same direction that Kant did; we cannot be satisfied with the mere reference of concepts to the purely sensuous schemata, to the 'perceptual forms of space and time.' For it is precisely these schemata which have lost their universal significance through the discovery of non-Euclidean geometry on the one hand, and the results of the special and general relativity theories on the other.* (DI: p. 166)

Cassirer might have been particularly motivated by the overall sense of a "crisis of intuition" as put forward centrally by the mathematician Hans Hahn in a lecture in 1920.[55] Developments like projective and non-Euclidean geometries and Georg Cantor's prove of the one-to-one correspondence between a line segment and all the points in an *n*-dimensional space, showed for Cassirer that gradually the methodological criterion of the "visualizability" (*Anschaulichkeit*) of theories was diminishing.[56] (DI: p. 169) As Nagel rightly put it in his review of *Determinismus*, the crisis of modern physics was according to Cassirer a crisis "with respect to the naïve demand that Nature (i.e. a complex of relations) be picturable or intuitable." Nagel continued: "[T]hus while physical theories must be controlled by experiment and observation, the theories themselves are not matters to be pictured or intuited in a sensory way."[57]

It is worthwhile to shortly repeat here a part the correspondence between Gottlob Frege and David Hilbert, for their thoughts on the matter deeply influenced Cassirer's. It seems natural to suggest that a mathematical—or physical—theory needs first and foremost secure knowledge of what its basic elements are. We need to know what "geometrical distance", "numbers" or "atoms" are before we can decide what statements about them are true. This assumption was deeply challenged before the turn of the nineteenth century. Among others,

---

[53] Cohen 1902 p. 24.

[54] See also: Friedman 2000 p. 95.

[55] See: Hahn 1933. Talk of a crisis in science was pervasive. See also the 'Die Krise der "Wirklichkeit"' debate between Riezler (1928) and Ludwik Fleck (1929) in which the new quantum mechanics played a central role. Also well-known is Edmund Husserl's *Die Krisis der europäischen Wissenschaften und die transzendentale Phänomenologie* (1936) which was concerned with alienation (*Verfremdung*), the meaning of life in light of scientific objectivity and the life-world (*Lebenswelt*) of human beings as opposed to the "natural attitude" (*Natürlichen Einstellung*) characteristic of the world of science.

[56] For a more careful analysis of how modern mathematical developments demonstrated for the young Cassirer the diminishing of the role of the Kantian intuitions, see: Ryckman 1991.

[57] Nagel 1938.

Frege and Hilbert challenged the gospel and found that our decisions about which statements are true and which are not often leave undetermined the meaning of the employed concepts.[58] In a letter to Hilbert, Frege expressed that traditional view assumed that "axioms and theorems can never lay down the meaning [*Bedeutung*] of a sign or word that occurs in them". Therefore, it was held that their meaning "must be already laid down [in them]."[59] With modern mathematics, however, the meaning of the "signs" or "words" was only of arbitrary importance as expressed by Hilbert in his response to Frege: "In other words: any theory can always be applied to infinitely many systems of basic elements… All the statements of the theory of electricity are of course also valid for any other system of things which is substituted for the concepts magnetism, electricity, etc. provided only that the requisite axioms are satisfied. But the circumstances I mentioned can never be a defect in a theory, and it is in any case unavoidable."[60] For that reason, Hilbert suggested, our intuitions connected to what we believe the theory describes can be regarded as superfluous or even misleading.

Later on, when Cassirer wrote *Determinismus* 1937, Niels Bohr's famous concept of the "complementarity" of our descriptions of physical reality had further complicated matters. Bohr's principle of complementarity declared that measurement reveals either matter its particle characteristics or its wave characteristics. The advocacy of both the wave picture and the particle picture of matter became exceedingly cumbersome for those who wished to solve this intuitional paradox which was central to the development of quantum mechanics. (DI: p. xx) Both classical views were necessary in order to give an exhaustive mathematical description of phenomena but insufficient in order to depict nature in an unambiguous way. But, when concepts do not derive their meaning from the intuitions or the senses, the meaning of science as a whole is not obvious anymore. Science must in some way be connected to the world we live in, a world of which we assume had has the capability of being represented.

Intuitions, as Cassirer informed us in 1937, can be "saved", but only by acknowledging the discursivity with which thought proceeds according to clear rules and their immanent limitation of our representations:

> *When the fundamental task of physical knowledge, the connection of phenomena into firm orders according to law, demands a duality of description, the habits and demands of intuitive representation and understanding must be subordinated to this fundamental requirement.* (DI: p. 213)

Cassirer observed that the "same basic syntheses [*Grundsynthesen*] upon which mathematics and logic rest, also govern the scientific structure of empirical knowledge".[61] Herewith, the separation between intuition and concept dissolved into an "ever more clearly into a pure *logical* correlation."[62] An abstract "symbolic" and purely *deductive* conception of theory was

[58] Gower 2010 p. 80.
[59] Frege 1980: 27-12-1899.
[60] Frege 1980: 29-12-1899.
[61] Cassirer 1907a p. 45.
[62] Cassirer, 1907b p. 698. See also: Friedman, 2000, p. 91.

on its way: “Physical research is never satisfied with bringing laws into a definite order *alongside* each other. Physics asks how one law comes forth out of another, it seeks a rule by which thought may be guided from one law to another.” (DI: p. 45) As I will discuss in part II, this seeking of a rule for thought was of crucial importance for Cassirer with respect to the principle causality.

4 CASSIRER'S FUNCTIONAL THEORY OF KNOWLEDGE

As we will gradually move toward the critique on Cassirer's *Determinismus* in part II, I will here make some general remarks on Cassirer's theory of knowledge. Thereafter, I will have a short look at the important debate on relativity. As a prelude to part II, I will end part I with a discussion on some of the most important issues with Kantianism expressed in the responses on Cassirer's book.

Cassirer's epistemology was centrally based upon his distinction between substance-concepts and function-concepts as put forward in 1910 in his first systematic work *Substanzbegriff und Funktionsbegriff: Untersuchungen über die Grundfragen der Erkenntniskritik*. In 1938, more than two and a half decades later Nagel vividly summarized Cassirer's viewpoint by saying that he made good use of the abstract character of quantum mechanics in order to "support his view that for theoretical physics Nature is not a set of objects but a complex of relations, in which functional interconnections replace self-subsisting and inaccessible substances."[63] Cassirer's incredibly rich intellectual historical writings were the result of an ongoing attempt to reveal in science an epistemological tendency to trade concepts that were based upon a notion of substance for concepts that were more suitably characterized by a notion of function. (SF p. 269) The notion of function-concept lay at the core of Cassirer's philosophy. Yet, the idea was not wholly new.

Kant had already spoken of functions:

> *Whereas all intuitions, as sensible, rest on affections, concepts rest on functions. By 'function' I mean the unity of the act of bringing various representations under one common representation. Concepts are based on the spontaneity of thought, sensible intuitions on the receptivity of impressions.*[64]

The faculty the sensibilities was understood by Kant as a thoroughly passive and receptive faculty. In short, intuitions and sensual impressions are delivered to us. Marburgians, however, rejected the idea that such a faculty could exist independently of the faculty of the understanding, which provide thought with concepts. Concepts were for Cassirer an expression of the ability to arrange the various contents of knowledge in a clear order, the ability which Kant had called function. Contrary to intuitions and sense-impressions, the process in which thought achieves order was understood as fundamentally active and productive. This activity of reason was taken to be one of the central characteristics of theoretical science.

[63] Nagel 1938. Friedman, Heis and others call this view the "functional theory of knowledge". Cassirer also occasionally referred to it this way. See for instance: ET p. 450. Even though the title might not be entirely convenient because of associations with "scientific instrumentalism", we will stick to it because the term clearly designates Cassirer dismissal of theories of knowledge that rely on a notion of substance or some ultimately substratum of empirical reality.

[64] Kant 1998 A68/B93

4.1 Inductivism

The tendency toward function-concepts that Cassirer perceived in the development of scientific thought was intrinsically connected to Cassirer's attack on the epistemology of inductivism. Traditional logic is centrally based upon the concepts of *genus* and *species* and the operations of abstraction and specification. As a result, it explains the formation of concepts as the inductive ascending from sensory particulars to increasingly more general concepts. Objects have properties and on the basis of comparing their properties with those of others, we can find similarities and in turn group them in a system of classifications. Cassirer centrally dubbed this view of concept formation (*Begriffsbildung*) "abstractionism". Now, any logic based on such an understanding of acquiring concepts is characterized by a certain Aristotelian metaphysical import, namely that of ultimate and unchanging substances. It presupposes that we acquire knowledge of the properties of things that exist independently of human cognition. This kind of philosophizing could not capture the meaning of the procedures of contemporary exact science.

Let me explain why Cassirer thought so. Cassirer denied the "abstractionist" dualism between theory and reality: "Abstract theory never stands on one side, while on the other side stands the material of observation as it is in itself and without any conceptual interpretation." (SF p. 107) Moreover, he said, it is completely meaningless to question the existence of individual objects or things without somehow invoking the system of judgements in which the object or thing has arisen. (SF p. 197) Cassirer held like Pierre Duhem that observation fundamentally bears the marks of at least "some sort of conceptual shaping." [65] (SF p. 107)

Indeed, Cassirer wrote later in 1937, statements of measurement are the alpha and omega of the physical sciences as all physical statements must eventually refer to experience and statements of measurement. (DI: p. 31-32) The enlightenment philosopher Mill for instance maintained that a statement of natural law is nothing but a comprehensive aggregate of an indefinite number of individual facts. Locke agreed that knowledge generally stemmed from sensations and that imagination and memory only needed to represent these sensations in consciousness. Kant, however, strongly objected and said that sensations themselves could never give rise to a determinate object, let alone a concept. Indeed Cassirer concurred, contrary to what abstractionists would think, not in any point in science do we see "the questionable and precarious *inference*" of induction, an inference leading "from some cases to many and from many to all". (DI: p. 41) Induction, Cassirer held, is a riddle and cannot explain the transition from statements of measurement to statements of law (DI: p. 39-40) The "steps" between statements of measurement and statements of law, and also those between statements of law and statements of principle, are essentially non-inductive. Rather, these inferences are "jumps" as they present us with an increase in knowledge rather than a reduction. In a kind of *Aperçu* scientific reason deals with discontinuous steps between various *kinds* of statements rather than with various quantifiers, as "some", "many" and "all".[66]

---

[65] Like Duhem Cassirer argued that no single empirical statement of natural science can be confirmed atomistically. For further reading on the topic of the relation between Cassirer and Duhem see: Ferrari 1995. The attempt to do justice to the Duhemian correlational character of knowledge was recognized by Frank in his review of *Determinismus*. (Frank 1938, p. 75)

[66] See also: ET p. 237-240.

Cassirer expressed that a fundamental paradox arises and said that this paradox is the main drive of the systematic investigation of nature: the old Kantian conflict between a necessary attachment to some *fundamentum in re* and the insight that it is a false hypostasis to think of nature as existing independently by itself as some kind of passive agent. (DI: pp. 119-120) In a sense, the problem was very similar to that of neo-positivism as both neo-Kantians and logical positivists sensed that their insights concerned "semantics" rather than "ontology". In general, the animosity against naïve strands of realism was not based on "what there is" but on "how we mean".[67] The common enemy was thus not per se a theory of the real, but an opinion on how we can know or speak objectively. Nonetheless—and this was not seldom the cause of much disagreement and even confusion—philosophers eventually often expressed their positions by statements in terms of "what there is and what there isn't."[68]

4.1.1 The picture theory

Additionally, Cassirer argued that the Aristotelean assumption of underlying substances essentially relied on the assumption of the "mirror properties" of representations. This is known as the "picture theory of language" or the "correspondence theory of truth". The picture theory was at least partially endorsed by Kant himself as he wrote: "The *nominal* definition of truth, that it is the agreement of [a cognition] with its object, is assumed as granted"[69] Kant pointed out, however, that the definition based on this "agreement" is *only* nominal. It explained the meaning of a linguistic expression, but it did not at all allow us to ascertain whether a cognition actually agrees with its object. This is so, he said, because the object is always presupposed to exist somewhere outside of cognition and is at the same time only given through our cognition of it: "For since the object is outside me, the cognition in me, all I can ever pass judgment on is whether my cognition of the object agrees with my cognition of the object."[70] As a result, the picture theory ends up in an explanatory circle and one is inclined to draw the sceptical conclusion that knowledge is impossible. Cassirer took this problem of truth as a starting point. Instead relying on the ability of thought to "copy" a pre-given reality, he would distinctively tend toward what is nowadays sometimes referred to as the "coherence theory of truth".[71]

4.1.2 Implications for empiricism

Instead of the empiricist reliance on the human capacity to abstract from the constant appearances in order to attain concepts, Cassirer proposed, like Kant, a more "top down" approach. In this sense, the actual practice of science can be characterized as "bottom up", working from tentative and sometimes heuristic and *ad hoc* assumptions that carry with them

[67] Coffa 1991 p. 232. According to Coffa this was essentially a nineteenth-century disposition and extended to neo-Kantianism and neo-positivism in the next century.

[68] Ibid.

[69] Kant 1998 A58/B82.

[70] In the *Jäsche Logic*: Kant 1992 pp. 557-558. Also here, Kant defines again what that the "mere nominal definition" of truth is the agreement of cognition with its object.

[71] Felix Kaufmann also remarks this and explains that the coherence theory of truth does not only designate knowledges' freedom of logical contradictions (consistency), but also particularly its foundations in the application of methodological principles. (Felix Kaufmann 1949 p. 142)

the promise of systematically describing a wide range of phenomena. Revolutions in science always start at the bottom. Throughout his life Cassirer defended that a theory of empirical science should, in contrast, not be characterized by its correspondence to phenomena but by "its methods; by our manner of dealing with scientific systems; by what we do with them and what we do to them."[72] A theory of knowledge can only later capture the broader conceptual continuity and unity.

Many theoretical concepts do not correspond to anything observable or measurable at all but have meaning only through the theoretical structure in which they are embedded, Cassirer reasoned. What was crucial for Cassirer, and also for Duhem, was that the concepts of a theory do not necessarily refer to a world "out there" but, more importantly, that they form, together with observations, a harmonious whole. That sensual experience shows a certain order can only point toward a conception of theories as systematic and coherent relational wholes that are in no way reducible to the collection of relations between its elements and *simple* sense impressions. Instead of relying on something like the correspondence of all individual elements of a theory to reality—a theory's total truth value so to say—Cassirer proposed that valid theories are only tied to experience through the observations that the theory *allows* us to make.

The Baconian notion of a "crucial experiment"—and therewith all kinds of Baconian empiricism—had fundamentally failed to grasp the proceedings of modern science. Cassirer formulated this clearly in 1944 in *An Essay on Man*:

> [*N*]*o conclusive disproof of a theory can ever be produced; for it is always possible to say that the experimental results are not reliable, or that the discrepancies which are asserted to exist between experimental results and the theory are only apparent and that they will disappear with the advance of our understanding. ... If you insist on strict proof (or strict disproof) in the empirical sciences, you will never benefit from experience, and never learn from it how wrong you are.*[73]

4.2 Structure

How can we understand physical reality when we conclude that the assumption of an underlying substratum is flawed? For Kant, the existence of objects could only be affirmed in a purely regulative sense, that is, as a purely imaginative focus of reason.[74]

> *The object always remains unknown in itself; but when by the concept of the understanding the connection of the representations of the object, which are given to our sensibility, is determined as universally valid, the object is determined by this relation, and it is the judgment that is objective.*[75]

[72] Cassirer 1944 p. 50.
[73] Cassirer 1944 p. 50.
[74] See on regulativity for instance: Kant 1998 A648/B676.
[75] Kant 1783 §19.

Like all presuppositions of pure reason, existence does not determine anything, it only guides us to a systematic unity.[76] True representations of the objects are established first and foremost through a systematic unity of thought. In turn, this unity enables intuitional unity. However, Kant's existence was related to the concept of the unknowable thing in itself.[77] This concept remained to play an explanatory role in Kant's transcendental psychology which was *ex hypothesi* impossible, since the thing in itself can be neither known nor talked about.[78] But Kant had already also explicitly defended that rather than the objects between which the relations of science hold, the relations themselves are epistemologically primary:

> *All that we know in matter is merely relations (what we call the inner determinations of it are inward only in a comparative sense), but among these relations some are self-subsistent and permanent, and through these we are given a determinate object.*[79] (DI: p. 130)

Like Kant, Cassirer held that the object of knowledge can be represented in a true fashion only when it is the product of a larger system of objective relations. Moreover, Cassirer radicalized Kant's critique on the sensationalist theory of knowledge by a strict reliance on not directly representational structures:

> *We must choose between these two views of the world: either with empiricism we must assume as existent only what can be pointed out as an individual in the real presentation, or with idealism, affirm the existence of structures, which constitute the intellectual conclusion of certain series of presentations, but which can never themselves be directly presented.*[80] (SF p. 123)

We can say that Cassirer surpassed Kant because for him the "permanence" and "subsistence" of relations lead not to the category of substance, but rather to "function" and the category of "pure category of relation".[81] In terms of Cassirer's *Philosophie der symbolischen Formen* (1923-1929) we can say that the "representative function" (*Darstellungfunktion*) of thought made way for the "significance function" (*Bedeutungsfunktion*) of thought. When relying on the semantics of representation it is very unclear how reality corresponds to the laws of theory. However, when relying on the semantics of pure significance, it becomes clear that physics has moved on to a thorough axiomatization of its basic concepts.[82] (DI: p. 195) Whereas the

---

[76] Kant 1998 B321, B341. See also: Kant 1998 A668/B696.

[77] The concept of *noumenon*—designating the *Ding an sich*—was still very much based on the Greek term *hypokeimenon*, designating an underlying material substratum.

[78] (See footnote 41)

[79] Kant 1998 A285/B341.

[80] Expressions like these support recent views of Cassirer as a supporter of "structural realism". See for instance: Gower 2010, Schmitz-Rigal 2009, Cei 2009. See also Heis' rejection of such views on Cassirer: Heis 2014.

[81] Cassirer 1907a pp. 30, 31, 39.

[82] See: Krois 1987 p. 116.

representative function is generally characterized by the recognition of a division between an external object and a knowing subject, it is centrally recognized with the significance function of thought that the objects of knowledge are epistemologically secondary, as they are constructed through an interweaving of laws. In short, Cassirer's point was one of form, stressing the criteria immanent within thought itself by which it progressively "shapes being". Cassirer radicalized the dependence on pure reason by saying for instance that thought, including physics and mathematics, freely constructs its own path toward its *telos* of pure meaning.[83]

Three short examples enlighten what Cassirer had meant with structures, or functional-relations. First, Cassirer wrote that it is impossible to intellectually grasp the meaning of individual numbers without *first* grasping the whole structure of number as such. (SF p. 36) Cassirer was in this sense very much indebted to David Hilbert and Richard Dedekind, for they had shown for him that single numbers are not "there", possessing a reality that is independent of those of other numbers. The meaning of single numbers is fully dependent on the arithmetical structure they are embedded in.

Second, Cassirer also found of similar significance the new logic of relations, in particular in the work of Bertrand Russell. Russell's "theory of types" had centrally shown that "classes" and their "elements" must be completely different kinds of logical objects. Moreover, classes of elements were also distinctively different from classes of classes.[84] More specifically, Russell's "theory of relations" is called a "second order logic" because instead of expressing the more concrete relations between objects and their properties, this logic was designed to express abstract relations between predicates. In a way, the theory was dealing with relations between relations. Relations themselves also have properties of which basic examples are reflexivity, symmetricity and transitivity. In Cassirer's terms, the older kinds of logic still relied on the traditional concept of substance, whereas Russell's type was characterized by function-concepts.

Third, Cassirer addressed laws of nature in a similar vein as the modern developments in logic and mathematics. Like Russell's classes, natural laws are deductively based upon one another and must be treated as wholly different things than the observations they allow us to make. Moreover, as reflected also in Cassirer's essays on relativity in 1920 and 1921, the modern laws of nature were of a higher order, not simply expressing relations between measurable properties but relations that hold between the classical laws applying to those measurable properties. This was centrally exemplified by Einstein's principle of general covariance: the a priori demand of the invariance of the form of physical laws under arbitrary coordinate transformations.[85] Covariance was seen by Cassirer as one of the summits of objectivity and it is in this sense that Cassirer concluded that modern natural sciences do not typically deal with *things* but with *structures*.

---

[83] See for example: Cassirer 1929 pp. 4-5.

[84] As famously exemplified by "Russell's paradox" and also the "liar's paradox".

[85] Covariance was not only based on the principle of the relativity of movement but also on the absolute limit set to physical interaction by the speed of light. Einstein initially called his theory "covariance theory" or "absolute theory". See for instance: Sigurdsson 1992 p. 581.

4.3 The functional a priori

In a sense very similar to what I above have called structural objectivity, Cassirer reversed the traditional Aristotelean epistemology.[86] The reversal becomes clear seeing that Cassirer's philosophy displayed a concern not so much for truth but for objectivity. A correct theory of objectivity would subsequently lead us to accurate notions of *knowledge*, *truth* and eventually the *object*. However, Aristotelean logic had relied more or less on the reversed hierarchy: *object*, *truth*, *knowledge*, *objectivity*. Traditional epistemologies like Aristotle's were typically characterized by a reliance on a resemblance to material or empirical substance. A representation counts as objective knowledge when it is true, which is, in turn, is the case when it corresponds to its object. Moreover, we humans are able to attain objective knowledge by inductively arranging our sense-impressions of objects in an orderly fashion.

In modern mathematical theorizing, Cassirer argued, the order is reversed. This necessitates the study of science as an investigation into its invariant a priori. The meaning of laws cannot be derived from something external to them, that is, they are epistemologically unique and determined through what Cassirer called a "synthetic act of definition".[87] (SF p. 34) For that reason, we may say that for Cassirer, concepts should be studied as concepts. Without for example the universal a priori intuitions of space and time and the a priori concept of causality there would be no genuine experience. There would merely be subjectivity, that is, a chaotic flux of disconnected impressions. The reality of science suggests, however, that this is otherwise. Therefore, there must be certain higher level principles that provide "unity" and "permanence" to the contents of thought and thus function in service of objectivity. In short, a priori concepts allow that thought is interconnected:

> *Knowledge is described neither as a part of being nor as its copy. However, its relation to being is by no means taken away from it but rather grounded in a new point of view. … What we call objective being, what we call the object of experience, is itself only possible if we presuppose the understanding and its a priori functions of unity.*[88]

4.4 Proviso

Important to consider is that Cassirer's general proposal—that modern physics was better understood in terms of function-concepts instead of substance-concepts—was in no way an absolute conclusion. The tendency toward the functional point of view was by no means completely fulfilled with the arrival of relativity theory or with quantum mechanics. Cassirer expressed that with these theories no claim can be laid with regards to the ultimate character of being. In all cases the possibility of discovering ever more functional-relations always remained.

Moreover, in line with Cohen's idea of science as an everlasting "genesis" *toward* the ideal endpoint of absolutely objective relations, Cassirer's writing testifies that we also can

---

[86] See for instance: Heis 2014 p. 9.

[87] See also: Ryckman 1991 p. 67.

[88] Cassirer 1929 pp. 4-5.

only "genetically" approach the infinitely distant endpoint of the absolute a priori. Cassirer was an "idealist" about ideas, so to speak, holding that however invariant a notion or general principle appears to have been throughout the course of history, there is no absolute guarantee that they are definite. Cassirer already took notice of this in 1918 when he called this the "transcendental insight": "that the 'absolute' is not so much 'given' as 'set as a task.'"[89] Absolute a priori principles can therefore not be stated with perfect or apodictic certainty and always retain a tentative character: As theories and views of nature inevitably change "even within the pure concepts of nature a possible diversity of approaches" remain to be upheld. Within this diversity each can claim "a certain right and characteristic validity" that cannot be directly compared and measured with each other. (ET p. 447)

It was thus never Cassirer's goal to argue for a reductive case, saying that all the objects of empirical sciences are constituted exclusively in terms of functions-concepts.[90] In his later publication of *Determinismus*, Cassirer's claim took on an even "milder" form as his style of writing obtained a more tentative and mature character. Moreover, as we will see in part II, the abstract thesis of the development from substance-concepts to function-concepts was imbedded in Cassirer's more "concrete" request to reconsider the notion of physical object or physical state.

[89] Cassirer 1918 p. 320. See also: SF p. 321 and Kant 1998 A647/B675. (See footnotes 42, 301, 302 and 372)
[90] Ryckman 1991 p. 74.

5 KANTIANISM PUT TO THE TEST

5.1 Cassirer's essay on relativity theory

The two decades after the development of the special relativity theory—were extremely formative and challenging for neo-Kantian philosophy. Kant's philosophy represented the epitome of philosophy's earlier booked successes and there was a great variety of neo-Kantian scholars who worked insistently to maintain different elements of Kant's original critical philosophy in light of the revolutionary implications of the special and general theories of relativity.

Kant's appraisal of Euclidean-geometry as the definite structure of space was fundamental. Euclid's axioms laid down the universal Geometrical structure of space and had proved to be necessary constitutive principles for all the empirical sciences. Also, Kant had argued in the *Kritik der reinen Vernunft* that the assumptions of the existence of the absolute space and time as found in Newton's mechanics were necessary for the possibility of representation as such. Kant had believed that the "pure intuitions" of absolute space and time were the definite form in which physical statements are be made.[91]

Special relativity theory implied, however, that space and time were strictly relational concepts. All physical happenings were now believed to occur with a finite instead of infinite velocity, equal to the velocity of light. In effect, this meant that because a notion of absolute simultaneity could not any longer be maintained, Newton's definition of true motion with respect to absolute infinite space and time needed to be thoroughly revised. Einstein's view suggested that simultaneity had become a relative principle, depending "merely" on the frame of reference from which the measurements would be made.[92] Depending on the relative velocities of the respective reference frames of the observer and the object, the theory predicted that measurements of space and time intervals would result in different values for different velocities. Overall, these developments suggested that, in contrast with Kant, space and time could not any longer be presupposed as autonomous entities, but must rather be seen a structure that progressively emerges from the various lengths and times measured.

As Einstein's theory of relativity became more and more established, it also became more natural for adherents of relativity theory to conclude that the whole Kantian doctrine had to be given up. The Newtonian assumption of absolute space and time that Kant had believed in was simply contradicted by the different perceptions of length and time as the result of the

---

[91] This is a text book view of Kant's view of space which is in fact more nuanced. It is argued that for Kant absolute space is not necessarily imagined as an object or entity but only as an idea. This provides reason to consider all motion and rest as merely relative, Kant said. In the derivation of "true motions" from "apparent motions" we do not conceive of a pre-given absolute infinite and empty space. Rather, absolute space is a forever unattainable regulative ideal, because we must conceive of it as produced by an indefinitely extended process beginning with our human and earth-bound perspective. See for example: Kant 1998 A16-17, 99. See also Kant's *Metaphysische Anfangsgründe der Naturwissenschaft* (*Kant's gesammelte Schriften* (Berlin (1900)), 481–482, 560.

[92] Some, for instance Reichenbach, stressed that Einstein's operational definition of simultaneity was essentially based upon a convention.

relativity of simultaneity. Furthermore, Einstein's general theory of relativity theory affirmed the growing suspicion against Euclid's geometry that physical space was not flat but curved. In addition to the effects as a result of relative motion, the parameters of space and time would also give different values as an effect of either a gravitational field or non-inertial motion. The flat Euclidean space that Kant had relied upon was only a special case in an infinite range of otherwise curved spacetimes.

Challenged to critically test his ideas of the tendency of modern science to develop toward function-concepts and rid itself from the substantial point of view, Cassirer embarked on writing a philosophical interpretation. Besides a smaller essay, 'Philosophische Probleme der Relativitätstheorie' (1920), Cassirer centrally published his ideas in the well-known essay *Zur Einstein'schen Relativitätstheorie* (1921). Cassirer granted that the Kantian system had to be drastically generalized. Indeed, Cassirer agreed with Kant, the Euclidean mathematics of space was according to Cassirer constitutive for the classical or "ordinary" human experience. But, since relativity theory also affirmed the physicality of curved Riemannian manifolds that did not coincide with ordinary experience, the transcendental idealist notions of space and time had to be stretched out enormously.

Cassirer was at pains to show that at the expense of Kantian orthodoxy, more generalized and invariant versions could still be retained. This endeavour led Cassirer to say that relativity obeyed to certain higher-level principles that were ultimately guided by the regulative a priori principle of "spatiality". (ET p. 433) In contrast with the presupposition of space and time as independent entities, relativity presupposed space and time "in the sense that it cannot lack the form and function of spatiality and temporality in general". (ET p. 418) Like Minkowskian spacetime, Cassirer's spatiality could be seen as incorporating both the demand of space and time. Spatiality is a regulative condition of the theory for it is fulfilled "quite without regard to its character in detail" and without assumptions concerning the "special relations of measurement." (ET p. 433) Although this general meaning of spatiality was already contained in Kant's original writings, he had indeed not always grasped his pure intuitions "with equal sharpness", Cassirer said. Cassirer critically took it up for Kant and said that in Kant's case "more special meanings and applications were substituted involuntarily" for the more general meaning of pure intuition, which is "merely that of the serial form of coexistence and of succession." (ET p. 418) Like relativity theory, the critical idealist view does not presuppose space and time as some*thing* that is already given. Pure ideal space and time, Cassirer said, are presupposed only in Kant's sense of the coexistence of things alongside one another and their general succession, one occurrence following another.

Cassirer thus strictly separated the pure concepts from their sensuous instantiations and particular schematizations.[93] As such spatiality has no "form" yet, it merely regulates all the constitutive and empirical concepts employed to understand physical occurrences in empirical space and time, Cassirer said. The general a priori requirement was only further specified by Einstein's concept of the linear element (d*s*) as determined by the metric tensor, the central relation in general relativity, expressing the effects of non-inertial movement and

[93] Sundaram explains that Cassirer's understanding of these general a priori principles can therefore be called "pre-critical". (Sundaram 1972 p. 41)

gravity in terms of a geometrical and causal structure of spacetime. Likewise, the absolute requirement of physical events to take place in some sort of spatiality incorporated as a limiting case Kant's highly restrictive space and time. Relativity theory reduced the philosophical status of Kant's pure intuitions of absolute and flat space and time to being *merely* the constitutive principles of Newtonian mechanics.

5.2 Rise of logical positivism

Before discussing the reception of *Determinismus* it is worthwhile considering Cassirer's view on relativity theory in light of the tensions between logical positivism and neo-Kantianism. In the years to come, the positivist philosophers Schlick and Reichenbach were of particular importance in the debates on relativity. Moreover, Schlick particularly criticized Cassirer's treatment of relativity. This affair had a considerable impact on the general reception of his philosophy of science and consequently on the reception of *Determinismus*. Below, I will shortly consider Reichenbach's views and thereafter Schlick's response to Cassirer's essay. First I will shortly highlight their similar "*ethos* of philosophy", as Cassirer called it.

Positivism has always been described as an anti-metaphysical philosophy. Kant had also been highly critical of metaphysics, but his reasons and understanding of how the metaphysical tendencies of thought could be tamed were wholly different. Logical positivism, as centred in the 1920s around Moritz Schlick, who had followed up Ernst Mach's chair in Vienna and founded the *Wiener Kreis*, developed further Mach's phenomenalism and came to claim that the truth of all claims to knowledge, must, eventually, be grounded in empirical evidence. Against synthetic Kant's a priori, Schlick held that such statements are either self-evidently true as they are based on definitions, or that they should thus be discarded as metaphysical, as they are not capable of being verified or falsified by the evidence provided by experience. What is cognitively meaningful in a philosophical statement is eventually determined by its empirical consequences.

Schlick views showed some surprising similarities to those of Cassirer. Especially their approaches to philosophy were very closely related. Both authors took science as the basic material for their philosophy of science.[94] Schlick saw epistemology as the task of inquiring into the "universal grounds on which knowledge in general is possible."[95] In an unpublished work from 1930 Cassirer wrote: "In '*worldview*', in what I see as the *ethos* of philosophy, I believe that I stand closer to the thinkers of the Vienna Circle than to any other 'school'—The striving for determinateness, for exactitude, for the elimination of the merely subjective and the 'Philosophy of feeling'; the application of the *analytic* method, strict conceptual analysis—These are all demands I recognize completely."[96] Also, in 1930 the journal *Erkenntnis* noted in a short article called "Historical Remarks" (*Historische Anmerkungen*) the general influence of

---

[94] Disregarding for the moment that Cassirer famously also took much interest in the "fact" of culture. Cassirer's concern with mythical thought and his philosophy of symbolic forms got shape during a later stage of his live. Cassirer's scientific epistemology had by then already reached a mature form.

[95] Schlick 1918 p. 3.

[96] This text is taken from a document titled 'Zur "Relativität der Bezugssysteme"' which can be found in the Cassirer archive at Yale University. The text is quoted in John Michael Krois' 'Ernst Cassirer und der Wiener Kreis' (2000) and Heis (2012 p. 2).

neo-Kantianism on neo-positivism, referring specifically to Cassirer and Leonard Nelson. It stated for instance that just like the many neo-Kantians, the positivist *Berliner Kreis*, originally called *Die Gesellschaft für empirische Philosophie*, founded by Reichenbach took problems of logic and physics as starting points for "epistemological critique".[97] Like the *Marburg Schule*, Schlick and Reichenbach embarked their philosophical journeys by emphasizing strongly the scientific aspects of Kant's kind of rationality.[98]

5.3 A bad start

Schlick's and Reichenbach's views were deeply formed by their encounters with relativity theory. The maturation of their philosophies was spurred by "their efforts to clarify the precise sense in which the general theory of relativity, with its novel implications about the geometry of space, can be said to be an empirical theory".[99] In their continuous efforts they meandered between a reductive and strict kind of positivism, influenced strongly by Mach, and the excesses of Kantian and neo-Kantian a priori concepts and intuitions.[100] For them, relativity theory motivated a significant departure from Kantian philosophy and even from the neo-Kantian enterprise as a whole.[101] Furthermore, they aimed to defend the relativity theory's "empirical credentials" against two kinds of neo-Kantianism. On the one hand, they attacked those neo-Kantians that rejected relativity theory for its denial of Kant's doctrine of the aprioricity of time and Euclidean space as pure intuitions. On the other hand, they vigorously rejected attempts to reconcile general relativity with the original contents of Kant's works. Central in Schlick's attacks on the Kantian approach was a denial of the possibility of synthetic a priori principles, the possibility which, recall, neo-Kantians like Cohen, Natorp and Cassirer held so dearly.

Schlick's view came to be favoured by most physicists, including Einstein and as a result, logical positivism gained a monopoly on the philosophy of relativity theory.[102] Moreover, they even attained a temporary hegemony in the philosophy of science in general. Although Cassirer was aware of this, as his writing to Schlick in 1920 suggests, it is remarkable that Cassirer never published a response to Schlick's vigorous critique. (ECN 18: 23-10-1920) Arguably, it lay in Cassirer's character to avoid head on confrontation. Although perhaps less voluntary, as we will see in part II, this was also the case with *Determinismus* in the 1930s.[103]

---

[97] Neurath 1930 p. 312.

[98] See: Coffa 1991 p. 171.

[99] Howard 1994 pp. 46-47.

[100] Ibid.

[101] Coffa 1991 chapter 10. Skúli Sigurdsson summarizes that Reichenbach and Schlick, "Einstein's apostles", were so enthusiastic in abandoning their previous neo-Kantian breeding ground in part because they were "steeped in debates with other neo-Kantians who often relied upon immunization strategies." (Sigurdsson 1992 p. 579)

[102] On this topic see: Thomas Ryckman 2005 *The Reign of Relativity*: *philosophy in physics 1915-1925* (New York: Oxford University Press).

[103] Taking into account, of course, that some letters of Cassirer may been lost.

5.3.1 Hans Reichenbach

Reichenbach took a revisionist stance toward Kantianism that was very much inspired by the critical neo-Kantianism of his teacher Cassirer. In 1920 he concluded that Kant's critical philosophy had not been refuted by relativity theory. Moreover, there was no need replace Kant's principles. Instead, we should differently understand the status of the traditional a priori. Rather than understanding a priori concepts and intuitions, such as space and time, as being "valid for all times", a point of view that turned out to be incompatible with relativity, a priori concepts should be understood as "constituting the concept of the object."[104] Kant's a priori conditions of space and time therefore simply attained a "relativized" status with respect to other possible principles.[105] As a limiting case of those of Einstein's theory, they could nevertheless be seen as constitutive principles of what could be called classical experience. Reichenbach concluded, like Cassirer, that the a priori constitution of science could in principle drastically change over time, as Einstein's theory proved with respect to our understanding of space and time.

Additionally, Reichenbach held that a defence of Kant was thus possible, but only with the proviso that definitions of absolute regulative a priori principles—products of pure reason—cannot be "apodictically certain" and must for that reason be rejected. Kant had held that from the regulative ideas of pure reason, no conclusions about the rules constitutive of empirical reality could be derived.[106] As we know, Cassirer, as a transcendental idealist, held that even though regulative a priori principles are generally not apodictic and definitions of them are thus always provisional, reason necessarily strives toward such absolute invariants. Reichenbach, in contrast, concluded that the logical analysis of science must be based strictly on constitutive principles for they are, in contrast, neither absolute nor "independent of experience". Notwithstanding their historical or logical contingency, the object-constituting principles must be apodictically valid as they are analytically defined and deductively relate to one another. Even if constitutive principles, taken in isolation, seem to have unlikely or even no empirical circumstances that warrant their possible rejection, there is nevertheless a way in which they can turn out to be false, Reichenbach said. Within the context of other constitutive principles they entail important empirical consequences that allow for their verification or falsification.

5.3.2 Moritz Schlick

A decisive impulse to the reception of Cassirer's *Zur Einstein'schen Relativitätstheorie* came from the hand of Schlick when he wrote a ruthlessly critical response that was published in

[104] Coffa 1991 p. 191. See Reichenbach's 'Relativitätstheorie und Erkenntnis Apriori' (1920).

[105] Flavia Padovani argues, against what is generally presupposed by e.g. Friedman, that the idea of the relativized a priori is already found *in nuce* in Reichenbach's doctoral thesis of 1915 entitled 'Der Begriff der Wahrscheinlichkeit für die mathe-matische Darstellung der Wirklichkeit', instead of in his 1920 monograph on relativity theory. (Padovani 2011 p. 2)

[106] See for instance: Kant 1998 A648/B676.

Kantstudien in 1921.[107] The arguments in his article entitled '*Kritizistische oder empiristische Deutung der neuen Physik?'* were not only constructed to deny the possibility of Cassirer's interpretation. Any neo-Kantian explanation of the new physics was deemed impossible, even Reichenbach's. Like Reichenbach, Schlick denied that there could be no absolute a priori concepts. Moreover, Schlick even attacked what was arguably the central impulse of Kantian and neo-Kantian philosophy as a whole. As he already claimed in 1918, Schlick said that there was no such thing as a synthetic a priori judgement: "*Es gibt keine synthetischen Urteile a priori*."[108] Hereby, he vigorously rejected the possibility of saving neo-Kantian critical epistemology.

Schlick's general views were remarkably close to Cassirer's.[109] He almost fully embraced Cassirer's critique on abstractionism and his functionalist alternative. The core difference was, however, that Schlick believed that all judgements are strictly either empirical or definitional. All knowledge consists of a posteriori synthetic judgements or a priori analytic judgements. Kant had centrally argued for the existence of judgements that were both a priori and synthetic. This was understood as a type of judgement that was non-empirical but nevertheless fundamental because, recall, Kant held that in contrast with analytic judgements thought is also able to productively arrive at new content. Kant famously took Euclidean geometry to exemplify this type of knowledge. Against Kant, Schlick argued that all a priori knowledge was a matter of definition and must thus be analytic.[110] Because Reichenbach also made this move toward an understanding of the a priori as an analytic matter of definition, Reichenbach could therefore not be properly called a Kantian, Schlick saw. Schlick nonetheless venerated Reichenbach's approach by demanding of an epistemology that it is valid only when it is able to "exclude some conceivable scientific developments and to conform to our best scientific theories."[111]

Schlick found that Cassirer's essay was nothing better than a retreat to an unacceptable level of vagueness and generality. Recall that Cassirer had separated the pure concepts of space and time from their sensuous counterparts and that he held that Kant had not clearly separated the general regulative conditions from its more concrete empirical instantiations. Further restrictions on spatiality itself could not be derived from the general principle of spatiality as it only regulates the more specific and relative principles of space and time, constituting of the objects of physical theory, Cassirer said. Schlick remarked, however, that it did not suffice to treat the conflicting physical descriptions of space and time as *merely* empirical space and time.

---

[107] Cassirer was not the first neo-Kantian whose philosophy was attacked by Schlick. Earlier, Schlick had already taken on the challenge of criticising Paul Natorp's and Richard Hönigwald's neo-Kantian interpretations of relativity theory in 1915.

[108] Schlick 1918 p. 327 (p. 384).

[109] Cassirer noted that in *Allgemeine Erkenntnislehre* (1918), Schlick took over the core thesis from Cassirer's *Substanzbegriff und Funktionsbegriff* (1910). See: Cassirer 1927 (ECW 17) p. 62.

[110] Schlick was in this sense very close to Poincaré's conventionalism. See: Schlick 1921 p. 333.

[111] Coffa 1991 p. 205. Schlick objected to Reichenbach's account of the a priori that his principles, always carrying in combination with others some empirical consequences, could not sufficiently be distinguished from the a posteriori. (p. 203)

It seemed that for Cassirer the topics were of no great philosophical value:[112] "Any claim about content, however general it may be, already seems too special here," Schlick said mockingly.[113]

Before writing his review, Schlick had sent Cassirer a letter in which he asked him to clarify precisely wherein lay the synthetic a priori element of modern science. Schlick incorporated Cassirer's reply in his review: The true a priori of science may "really consist only of the idea of the 'unity of nature', that is, of the law-abiding character of experience in general [*der Gesetzlichkeit der Erfahrung überhaupt*]".[114] Moreover, Cassirer added in his letter, these principles may be regarded as a "pure expression of reason [*Vernunft*], of logos itself". (ECN 18: 23-10-1920) However, Cassirer's elaboration on the synthetic a priori only fuelled Schlick's critique. Just like the unitary obedience to the law-abiding character of experience in general, Schlick said, Cassirer's principle of spatiality is a *conditio sine qua non* of science.

Indeed, scientific theories were in Cassirer's eyes unable to pose a threat to the synthetic principle of the "unity of nature". This transforms Kantianism in a doctrine incapable of refutation, Schlick said and thereby accused Cassirer's philosophy of being unscientific. What was astonishing, however, was that Schlick generally took Kantianism and neo-Kantianism, including Cassirer's approach, as centred around the recognition of synthetic a priori concepts that were both constitutive and apodictic.[115] In his rebuttal of Kantian interpretations of relativity Schlick did not pay much attention to the regulative status of pure concepts. For Kant, the most important synthetic a priori principles had been regulative. In the *Critique of pure Reason* Kant had explicitly defended that existence, the *Ding an sich*, the free will and God were regulative ideas. Even though Cassirer gave up on the apodicticity of the a priori, he had also insisted on spatiality as a purely regulative ideal. His explanation of the high point of the synthetic a priori as the regulative ideal of the lawfulness of experience, attacked by Schlick in his review, would be further taken up by Cassirer in his defence of causality in *Determinismus* sixteen years later.

Cassirer got somewhat explicit when generally discussing Schlick's epistemology years later in 1927. He wrote that Schlick's account of conventional definitions was in need of guidance and restriction by regulative principles, not as conventions but as a fundamental expression of human reason. This implied that Schlick's rebuttal of Cassirer's a priori had never been complete. Yet, Cassirer noted that the greatest relation to Schlick's philosophy was not their difference of opinion but their mutual agreement.[116] In his response to Schlick's letter, Cassirer remarked that perhaps his published essay stood much further from the physicist's understanding of the whole matter since he spoke in a language that might be foreign to them. Cassirer suggested that Schlick's point of view probably had a much higher potential of achieving a mediating position between physics and philosophy. (ECN 18: 23-10-1920)

---

[112] Schlick 1921 p. 323.
[113] Schlick 1921 p. 326.
[114] Ibid.
[115] Schlick 1921 p. 323.
[116] See: Cassirer 1927 (ECW 17) pp. 67-79.

6 SOME ISSUES WITH KANTIANISM

As a preliminary to the discussions on causality, continuity and finally determinism and indeterminism, I will here discuss some of the difficulties with the neo-Kantian enterprise that physicists spoke of in their comments on *Determinismus* in 1937 and 1938. The discussion clarifies generally how neo-Kantianism was perceived and consequently throws some light on the reception of *Determinismus* as a neo-Kantian interpretation of quantum mechanics.

6.1 History of science

Max Born believed that the main tenor of *Determinismus* was the endeavour to prove that the apparently “revolutionary” moments in modern physics have actually been completely in line with the normal development of the natural sciences.[117] (ECN 18: 19-3-1937) It is therefore worthwhile to consider first Cassirer’s unique style of philosophizing in deeply historicized way. With this approach, Cassirer significantly departed from the philosophies of his teachers Cohen, Natorp and, most importantly, Kant.

Cassirer advanced a philosophy of history which relied on the idea of a continuous convergence towards one final unitary structure that contains all the previous structures as *approximate* or *limiting* cases. Non-Euclidean geometries served to be an important example for Cassirer throughout his career, for a central aim of non-Euclidean geometries was to contain the traditional Euclidean geometry as a limiting case. In Euclidean geometry it was defined that for a given line *l* there is only one parallel for every point not on the line, that is, one other line that does not intersect *l*. In non-Euclidean geometries, in contrast, we are rather dealing either with infinitely parallels or none at all. Nonetheless, these curved geometries can approximate a flat one. Also, in relativity theory the laws of nature remain invariant under arbitrary coordinate transformations and different observed lengths and periods of time reach one classical limit when relative velocities, gravitational fields and inertial forces approach zero.

In quantum mechanics, when systems become sufficiently large with respect to Planck’s constant, the uncertainty of complementary observables approaches zero and the behaviour of objects is classical. However, quantum mechanics also radically broke with some fundamental classical principles in a way that could not be restored by thinking of limiting cases. For Cassirer, as we will discuss in part II, this was centrally seen in the violation of the classical and Kantian principle of “complete determination”. Quantum mechanical systems are intrinsically statistical and do typically not assign precisely defined values to all variables. With respect to the resulting “rupture” in the observable phenomena that quantum mechanics describes, i.e. the wave-particle duality, this implied precisely what had been one of the starting points of Cassirer’s “philosophy of symbolic forms”, namely that there is no unique image of

[117] What was important for Cassirer, as Born observed, was to understand the gradual and “infinitesimal” intellectual developments by which the scientific landscape *eventually* came to be radically different. (ECN 18: 19-3-1937) For Edgar Wind, the art historian and philosopher who had studied with Cassirer, his mentor was in this respect a pioneer. (ECN 18: 6-4-1937)

experience.[118] What physical reality—based upon the presupposition of a lawful order—ultimately "looks like", or how the systems that physics describes should ultimately be interpreted, is intrinsically dependent on the fabric of our theories and subject to perspectival change, even within one theory.

In combination with his intrinsically historical method, this was a direct reason for Cassirer's somewhat opaque style of writing. Somehow, the history of science suggests a non-positivistic style of thinking and writing.[119] Since history is full of ambiguities, unclarities, change, opposing world views, conflicting opinions and so on, it seems natural to write in a way that is characterised by perspectival change. Not every point of view, line of thought or motivation for action can be translated one-to-one into another and the possibility of a rigorous evaluative comparison of ideas is therefore not always possible. Even if all different ideas and worldviews of historical actors would be "commensurable", to use a present day term, crystal clear comparative analysis is often at the price of historical content since the various opposing positions within the scholarly debates and controversies were often not as clear-cut as they may appear in retrospect.

Let me take a moment to set out the evolution of thought and knowledge as put forward in the *Philosophy of Symbolic Forms* (1923-1929) for it generally illustrates Cassirer's aims in *Determinismus*. Cassirer generally understood all manifestations of knowledge as symbolic forms: myth, "ordinary" sense perception or theoretical scientific developments. The most important type of meaning in Cassirer's philosophy of symbolic forms is for us the *significance* meaning, a product of the significance function (*Bedeutungsfunktion*) of thought. Modern theoretical science is characterised by it and it is exhibited most clearly in the "pure category of relation".[120] It is only hesitantly grasped by natural language, because, as was discussed above, the formal concepts of modern logic, mathematics and mathematical physics have shown to be freed from the sensible bounds of intuition.

Cassirer's continuous emphasis on the more basic and primitive types of symbolic meaning represented a decisive break with his Marburg predecessors. Discussing "ordinary"

---

[118] See generally: Cassirer 1929.

[119] Sigurdsson has put forward why also this imperative is at least partly influenced by historical factors. His reasoning also applies to the case of Cassirer. (Sigurdsson 2007 p. 152) We can assume that the fruitful investigative pathways Cassirer took in his reflections on science were at least in part blocked by, on the one hand, neo-positivism, who arguably attained a monopoly in the philosophy of science and openly abandoned neo-Kantianism, and, on the other hand, by Cassirer's forced exile, losing as a result of World War I fertile philosophical ground also in a geographical sense. Given these premises, we can say that the recent renewed interest for Cassirer's philosophy of science is great news. The reason is twofold: Historians of science need to acknowledge what Sigurdsson describes as "the inadequacy of their positivistic tools when venturing into the explorative space of trauma." In this respect, the influence of the destruction of the two world wars and the suppressed memory of German Jewry on the history of science cannot be understood without considering culture and collective memory, to name but two things. On the other hand, renewed interest in Cassirer allows contemporary philosophy of science to trace back its lineage also to neo-Kantianism and thereby produce at least some counterweight to the analytic tradition which came forth out of neo-positivism.

[120] Cassirer 1907a pp. 30, 31, 39.

sense perception and the world view of myth were continuously on his agenda. Natorp had already hinted at the unity of culture, meaning that the transcendental method should also examine the facts of custom, of art and of religion.[121] Cassirer would further develop and emphasize more strongly this perspective with studying other "facts" such as language and myth.[122] Cassirer's encompassing approach to philosophy herewith provided a possibility of a "critique of culture" and at the same time questioned the Kantian triadic model of logic, ethics and aesthetics, taken over by the Marburg School.[123] It was a priority throughout Cassirer's career to stress that all symbolic forms were equally valid ways of knowing.[124]

This did not, of course, justify savagery, but meant that the basic symbolic forms did not necessarily compete with the more advanced ones. In doing so Cassirer embedded the Marburg "fact of science" within a much more general "fact of culture" as a whole. Cassirer attempted to understand science and its a priori in a more comprehensive intellectual history. His in this sense Hegelian framework aimed to capture the most general forms and categories of human thought by embracing a conceptual history of all human culture as a whole.[125] In *An Essay on Man*, published in the year before his sudden passing, Cassirer explicitly defended that science is man's highest achievement. Yet, he also immediately nuanced this image by saying that the typical "constructiveness" it displays has its roots in language, religion and art.[126] As a shocking result, the natural sciences fell of their throne of being somehow truer than myth or sense perception.

Cassirer's style of writing is in no way easily digested. Cassirer's style of writing and thinking, presenting arguments, which was arguably based on analogy and emphatic demonstrations instead of deductive or inductive derivations, inferences or proofs, starkly contrasted with the logical positivist preference for clear unambiguous assertions, stated ideally with mathematical precision.[127] Philipp Frank, warned in his review of *Determinismus* for the contrast between scientific terminology and Cassirer's more peculiar statements. Frank said that the author regarded every rehearsal of the statements of science as more than just a superficial repetition. They suggested a much deeper meaning. Usually, however, the suggestions are merely hint at and not described in detail, Frank said.[128] Moreover, it was not Cassirer's purpose to resolve contemporary controversies within the various sciences. In line with Cassirer's previous *Substance and Function* and the *Philosophy of Symbolic Forms* he

[121] Ferrari (2009) also writes that Cassirer's philosophy of symbolic forms is remarkably in line with Natorp's later "ontological interpretation" of transcendental philosophy.

[122] Ferrari 2009 p. 294.

[123] Ferrari 2009 p. 297.

[124] Ryckman calls this "the relativizing thesis" of Cassirer's later philosophy. (Ryckman 1991, p. 75) This should not be confused with the relativization of the a priori that Reichenbach talked about when addressing the peculiar changeability of the constitutive a priori. For an example of the relativization that Cassirer speaks of see: ET p. 446-447.

[125] See for Cassirer's generalized and liberalized approach to a somewhat more Hegelian study of the "facts of culture": Ferrari 2009 p. 304. See also: Friedman 2002 p. 269.

[126] Cassirer 1944 pp. 220-221.

[127] See: Hempel 1975.

[128] Frank 1938 p. 71.

attempted to write in a way that was at peace with various contradicting viewpoints, only to later synthesize them in statements of higher generality. Frank appears to have been very aware of these implications:

> *Die Darstellung Cassirer's wird daher nicht eine kritik der modernen Physik vom Standpunkt des 'philosophischen Determinismus', aber auch kein Versuch, den philosophischen Determinismus mit Hilfe der modernen Physik zu verbessern, sondern Cassirer schreibt eine Untersuchung darüber, wie sich die Regeln und Gesetzmässigkeiten in der Physik ihrer Form nach in den letzten Jahren durch die Quantenphysik geändert haben*.[129]

Where Cassirer's mentors Cohen and Natorp at the Marburg school were mainly occupied with the synthetic principles constituting the origins of knowledge, Cassirer would most of the times suspend the question of an origin.[130] Therewith, Cassirer endowed his investigations with a more instrumental character, treating the foundations of science as describable yet not deducible "factualities".[131]

6.2 Is neo-Kantianism Kantianism?

Born wrote Cassirer that in *Determinismus* the name of the "great Kant" was used in light of the central aim to prove that none of his principals needed to be sacrificed.[132] (ECN 18: 19-3-1937) As we have seen, however, Cassirer was not so much concerned with a defence of Kantianism as a system of philosophical assertions as he was with working in the spirit of Kant's methodology, that of critical thinking and the "transcendental method". Some, however, believed either that this was such a far cry from the original Kant that Cassirer's philosophy could hardly be called neo-Kantian or that it was so general that every "critical" attitude could be called Kantian. Born, for instance, applauded to Cassirer's quest for historical invariant principles as something that he also likes to stress. He remarked that if Kantianism would be reduced to "being critical" he would like to call himself a Kantian: "*Wenn 'Kantianer' sein nur bedeutet: 'kritisch' sein, so möchte ich mich auch so nennen*." (ECN 18: 19-3-1937) However, Born explained, the word a priori was fatal for him because the Kantian orthodoxies associated with them were a stumbling block for the presenters of the "new thought".

Cassirer highlighted in his foreword to *Determinismus* that there had been "many critics who agreed indeed with the conclusions I had drawn from the development of the new physics but who supplemented their agreement with the question whether as a 'neo-Kantian' I was permitted to draw such conclusions." (DI: p. xxiii) *Determinismus*, Cassirer continued, would

---

[129] Frank 1938 p. 73.

[130] Cohen strongly objected to Cassirer's concept of function because it detached from the systematic "logic of origin" (*Ursprungslogik*). See: Ferrari 2009 p. 302.

[131] Felix Kaufmann 1949 p. 127. See also: Ryckman 1991 p. 62 and Marx 1975 p. 306.

[132] Born states that Kant is cleverly explained by Cassirer in a Leibnizian way. Cassirer did not elaborately articulate a Leibnizian reading of Kant in *Determinismus*. It appears therefore that Born was aware of some of Cassirer's more general developments. Therefore, we must turn centrally to Cassirer's first published work: *Leibniz' System in seinen wissenschaftlichen Grundlagen* (1902).

probably be exposed to an even greater degree of such questions. However, as Cassirer addressed the problem, this view was based on a terrible misconception. No scholar of the Marburg School had intended to hold fast unconditionally to Kant's system. Neither did Kant himself, they said. Cassirer steadfastly quoted his teacher Natorp, who said: "Talk of an orthodox Kantianism was never justified. … A poor student of Kant who understands otherwise!"[133] (DI: p. xxiii) The Marburgians generally hoped that—like Kant had expressed once concerning Plato—"one can understand an author by the comparative arrangement of his sentences better than he had understood himself."[134] In the end, their relation to Kant was no different from the relation between modern physicists and, say, Galileo. Like the physicist, the philosopher rejects all dogma. Moreover, both physicists and philosophers attempt to clarify and advance the ideas of their predecessors. For Cassirer, this meant that the epistemological principles fundamental to science develop—somewhat like science itself—in a way that the new regulative a priori principles always clarify the older ones.

6.3 Existence

Let's look at some of the more specific expectations physicists had of Kantianism and of Cassirer's neo-Kantianism. In a letter, Max von Laue attacked Cassirer's neo-Kantian claim that, in a strict physical sense, nature is nothing but the "embodiment" (*Inbegriff*) of relations and laws. (DI p. 148:) Indeed, Laue said, if we replace "nature" by our "knowledge of nature", the statement would be wholly true. But, for "nature itself" the "individual things" (*Einzeldinge*) are also important. Or, he asked humouristically, shouldn't we "count the Kattegat as a part of nature?"[135] (ECN 18: 26-3-1937) Laue herewith showed a deep concern for the classical and somewhat Kantian starting point that nature must ultimately be composed of individual things.

As Laue saw, Cassirer's epistemology was in no way addressing the existence of everyday objects like the Kattegat. What according to Cassirer is presupposed to exist by modern physical theories like quantum mechanics was something like the relational and lawful order embodied by the theory, not the individual entities. Also, Cassirer let go of Kant's original *Ding an sich* and maintained that even the inside of nature is always empirical and "for us". (DI: p. 135) This was not meant in a subjective idealist sense that nature is replaced by our knowledge of it, Cassirer explained. Nature is presupposed to be really there independently of our knowledge: Some attachment to a *fundamentum in re* must always be retained. (DI: p. 119-120) Moreover—and this is what Cassirer centrally wanted to show with his generalization of the causality principle, as we will see—this reality is always presupposed in the sense that natural phenomena are orderly and that this order can be grasped by intellectual effort.

Laue raised an important point, because Cassirer seemed to shun all talk of the existence of individual substances. Laue perceived that Cassirer abolished talk of the individual electron and its pathway through space and therefore critically commented that Schrödinger's

---

[133] Natorp 1912 p. 194.

[134] Hermann Cohen 1902 p. XI.

[135] The Kattegat is the sea area in between Sweden and Denmark that together with the Skarrerag and the Baltic Straits divides the Baltic See and the North Sea.

law showed, on the contrary, that the concept of the revolution of the electron is not fully disposed of. He wrote Cassirer that Schrödinger's law only replaces such revolutions with so-called "eigenfunctions" that arrange the levels of energy exactly in accordance with Bohr's of model of the atom. (ECN 18: 26-3-1937) However, Cassirer had written that from the functional point of view, saying that electrons "really" exist and move along specified pathways can be perfectly in order, but only when it is understood in Schrödinger's sense: The reality of the electron and its pathway is there only as an intersection of laws of nature objectively mediated by experiment: "[*E*]*s gibt für uns keine andere physikalische 'Realität' als diejenige, die uns durch die physikalischn Massbestimmungen und die auf sie gegründeten und insofern 'objektiven' Gesetzbestimmungen vermittelt wird*." (DI pp. 168-169:) For Cassirer, statements about the position, the orbital time and the pathway of the electron disappeared in quantum mechanics only when they are uttered in a substantialist sense.

Instead of abandoning of the idea of a corpuscle, Cassirer pointed toward the indivisibility of the charge of the electron.[136] (DI: p. 181) That there is an elementary charge justifies us speaking of the electron as a "determinate object" only when considering that the task of the "reification" (*Objectivierung*) of phenomena is not to be interpreted with respect to a "being that obtains *prior* to all experience" but rather as the "thought of a possible experience in its absolute completeness", that is, as constructed through the interweaving of laws and strictly limited to its conditions.[137] (DI p. 17: 19) For Cassirer, this suggested the interpretation of a creative activity of mind that exists purely of the determination and isolation of common quantitative elements in a not overseeable yet constructed multiplicity of interconnections and concrete things.[138] In as far as the concept of thing (*Dingbegriff*) is not the starting point but the *telos* of philosophical analysis, we are kept from a dualism between a thing-world and an idea-world.[139] Even though Cassirer's epistemology had strong constructivist tendencies and was preoccupied with physics primarily in the sense of physical *knowledge*, the central problem of epistemology remained for him to be the concept of physical reality.

6.4 Idealism

In a critical review of *Determinismus* published in *Theoria* in 1938, Frank wrote that Cassirer's statements generally appeared to be very positivistic. Ultimately, Cassirer strived for a anti-metaphysical interpretation of quantum mechanics and this, Frank said, was most convincingly shown by the confidence with which Cassirer rejects the idea that ethical conclusions can be drawn from quantum physics.[140] Reading his review, however, we cannot escape the impression that Frank thought that Cassirer was a logical positivist who was still in denial.

[136] Cassirer referred in this respect to the discussion between Laue and Schrödinger: Laue's *Materie und Raumerfüllung* (1933) and Schrödinger's response "Über die Unanwendbarkeit der Geometrie im Kleinen" (1934).

[137] See for instance: ET p. 447 or SF p. 107. See also: Felix Kaufmann 1949 p. 130.

[138] Felix Kaufmann 1949 p. 121-122.

[139] See on "thingness" and "lawfulness" for instance: DI: 131. (See also section 9.2.1)

[140] Frank 1938 p. 79. See for a great example of the anti-metaphysical stance the positivist manifesto *Wissenschaftliche Weltauffassung der Wiener Kreis* (1929) published by the logical positivists Hans Hahn, Otto Neurath and Rudolf Carnap.

Likewise, Nagel remarked in his review that on many important points it is only Cassirer's "Kantian piety" that distinguishes him from the logical empiricists.[141]

Frank's review enthusiastically concluded that *Determinismus* is a highly perceptive (*schardsinnig*) book. Frank generally admired Cassirer's knowledge of physics and stated that the book presented in clear and understandable language arguments that are of great use for every physicist and that it corrects some unfortunate misunderstandings surrounding some of the more recent developments.[142] Frank remarked that his own book *Das Kausalgesetz und seine Grenzen* (1932) was sometimes seen as a derogatory critique in the "Cassirerian direction", but, he wrote, the opposite is true.[143] The only difference with logical empiricism is that ultimately Cassirer blurred the borderlines with transcendental idealism but, Frank suggested, this might be merely a difference in style.[144] What is shared, Frank continued, is a certain stance against what Frank called "*Schulphilosophie*" (school philosophy). This meant for Frank that Cassirer's general aim was in line with the general tendency of positivism to "de-ontologize science" (*désontologiser la science*).[145] Like positivists, Frank concluded, Cassirer advocated a "scientific philosophy" which in effect suggested an announcement the end of philosophical idealism.[146]

Frank admired Cassirer's painstaking attempt to show that it is impossible to formulate causality as a specific law of nature. Instead of such a formulation, Cassirer ascertained one general form in all "causal contents". Such a general methodological form is, following Frank's remark, not a matter of ontology but a matter of cognition, not of *what*, if you will, but of *how* we know. Cassirer let go of some more specific formulations of causality provided by Kant, for example, the presupposition that for every event there is another one that can in principal be deduced following a certain rule. Indeed, Frank went on, Cassirer held on to Kant's more general formal demand, "*dass es überhaupt irgendwelche Gesetzmässigkeiten in der natur gäbe*", that is, that nature behaves in a lawlike manner.[147] But in doing so, Frank concluded, Cassirer's views are extremely close to those of Mach, whose views were central to those of the *Wiener Kreis*.[148]

However, Frank also saw that at many occasions *Determinismus* could not be fully grasped from the standpoint of logical empiricism. Often, Frank observed, the book hastily leaves behind the initial scientific attitude and makes a "turn to metaphysics" (*Übergang zur Metaphysik*). A most enlightening example Frank provided is Cassirer's treatment of the concept of "mass point". In essence, Cassirer had argued, this concept never be understood as

---

[141] Nagel 1938. In light of the connection with neo-positivism, Friedman maintains that Cassirer's later development can be seen as a kind of "heroic attempt to maintain a mediating or synthesizing position between the sharply opposed philosophical positions." (Friedman 2002 p. 263)

[142] Frank 1938 p. 70, 73.

[143] Stöltzner 1999 p. 87.

[144] Frank 1938 p. 72.

[145] This tendency was also brought forward by Frank in *Between Physics and Philosophy*: Frank 1941 p. 195.

[146] See also: Felix Kaufmann 1949 p. 139.

[147] Frank 1938 p. 72.

[148] (See footnote 152)

an impression or an image of physical things. It is for Cassirer a "form" who's meaning and content (*Sinn und Gehalt*) are found in its capability to lead to simple and strict phenomenological laws. It would have been fortunate if Cassirer simply meant with "form" that the concept "mass point" needs to obey certain rules of language and thus displays a certain syntactical structure. But, Frank went on, the word "form" is an unfortunate remainder of Kantian terminology, a terminology in which also space and time are "forms of experience" (*Formen der Erfahrung*). Stubborn misunderstandings arise because the Kantian talk of "forms" resists to be taken up within the coherent whole of physical statements. Such talk, Frank concluded, obscured the way a word like "mass point" should be understood, namely that when combined with other words according to precise syntactical rules, the concept is well suited for the representation of observations.[149]

Even the neo-Kantian Cassirer showed a preference for positivistic statements and this, Frank wrote in a letter to Cassirer, proved the "decomposition process" (*Zersetzungsprozess*) of "school philosophy".[150] (ECN 18: Frank *ohne datum* p. 176) This decomposition has only left standing some rudimentary talk of "forms" and "borders". But such an uncompleted critical attitude toward metaphysics, of which *Determinismus* turned out to be a paradigm case, Frank found, prevents us to clearly depict the scientific meaning of quantum physics. Even though Cassirer's characterisations of the "scientific-logical structure" (*wissenschaftslogische Struktur*) of the quantum mechanical "lawfulness" (*Gesetzmässigkeiten*) is striking, Frank concluded in a sense very much like Schlick's critique of Cassirer's relativity essay that a formulation of these structures in the language of idealistic philosophy is unscientific.[151] Also Schlick and Reichenbach had explicitly worried that Cassirer's Kantianism had been weakened so much that it only differed verbally from their own empiricism.[152] However, in Frank's view of positivism, this difference in style was not innocent as there was at least some danger in

---

[149] Frank 1938 p. 77.

[150] For "*Schulphilosophie*", see also: Frank 1932 pp. 283-286. Frank highlighted that similar things could be said of the philosopher Hugo Bergmann's book on causality in relation to quantum mechanics called *Der Kampf um das Kausalgesetz* (1929).

[151] Frank 1938 p. 77-79. (See footnote 149) Stöltzner finds that because of the convergence between logical empiricism and Cassirer's neo-Kantianism, Frank's review is "very laudatory". However, Stöltzner's article does not note that Frank was also very critical of transcendental idealism. Stöltzner remarks that one reason for the convergence is that both Cassirer and the positivist Mach understood the principle of causality in terms of "function". Although Cassirer might have indeed been influenced by Mach, Stöltzner hardly provides any evidence. Cassirer seems to have been very close to Mach looking at Mach's assertion that the classical intuitive concept of *substantial* thing is in modern physics replaced by the *relational-functional* concept of universal law. (Stöltzner 1999 pp. 89-90) However, Mach had insisted, like Boltzmann, that space and time were not a priori concepts, but abstractions from empirical experience. (Stöltzner 1999 p. 101) Cassirer centrally rejected "abstractionism". Moreover, Stöltzner even thinks that *Determinismus* is centrally "a justification of bestowing on Mach the honor" of having given birth to what Stöltzner calls "Vienna Indeterminism". (Stöltzner 2003 p. 11) This is completely at odds with Cassirer's rejection of indeterminism.

[152] See: Schlick 1921 and Reichenbach's *Philosophie der Raum-Zeit-Lehre* (1928).

wilfully shading the contours. One knows that the reader is often influenced more by the "emotional undertone" than by the logical-empiricist content, Frank warned.[153]

6.5 Methodological Kantianism

In light of all the various problems with neo-Kantianism, exemplified in our case by Frank, Laue and Born, it is worthwhile to note that Cassirer's philosophy was deeply modernized by a radicalization of what Cassirer saw as Kant's "methodological transformation". (DI: p. 17) Like Cohen and Natorp, Cassirer expressly took a priori principles to be "methodological presuppositions". For Cassirer, these principles were not transcendentally deducible but could only be demonstrated as continuities within the history of scientific thought.[154] The a priori was therefore intrinsically linked to historical progression of science. This appears to have been a much lighter version of the a priori than found within the original works of Kant. Yet, and Frank might have sensed this, it was also the general intend of the whole neo-Kantian enterprise to ascertain some higher structure of reason, that is, to reveal the essentially non-empirical workings of an eternal logos. This was indeed fundamentally at odds with any kind of positivism. Talk of absolute synthetic a priori principles was in general neither empirically verifiable nor falsifiable. As all knowledge is provisional in character, the Marburgians realized that instead of arriving pompously at a complete and exhaustive description of the a priori that would be valid once and for all, like Kant had appeared to claim, epistemology also always needs to be established tentatively.

Concerning the above issues with Kantianism—of which the most disconcerting was perhaps Frank's accusation of the "emotional undertone" of idealism—it is worthwhile here to discuss briefly whether Cassirer indeed was a neo-Kantian or not. Superficially seen, it is remarkable that in *Determinismus*, Cassirer rarely disagreed with Kant. Quotations of Kant usually functioned in support of Cassirer's arguments. Of course *Determinism* was not a book on Kant, and it indeed might not have been the right occasion to critically examine Kant's philosophy of physics, but Cassirer could just as easily have chosen to highlight explicitly were his thoughts differed from Kant's and where the new physics proved him wrong. This attitude clearly shows that Cassirer expected to be treated as a neo-Kantian. Besides being a defence of what I have called the functional theory of knowledge, *Determinismus* can also be seen as a defence of the spirit of Kantianism and it was therefore probably unfortunate for Cassirer to see that this was sometimes conflated with the more specific contents of Kant's writings.

Cassirer realized that with the further development of the Marburg School it lost even the remotest possibility of a "justification" as a school. The obvious reason was, as Cassirer put it, that "many of the theories ascribed to neo-Kantianism in the contemporary philosophical literature are not only foreign, but are diametrically opposed to my own views."[155] However, as Natorp had stressed, one crucial reason why one should want to go back to Kant, namely in order to pursue the fundamental insights which philosophy has irreducibly won through him in

[153] Frank 1938 p. 72.

[154] For the abandonment of the method of transcendental deduction, see: Kaufmann 1949 p. 127.

[155] Cassirer 1993 pp. 201-202. See also: Ferrari 2009 p. 295.

the direction of the eternal problems of philosophy.[156] For that same reason, Cassirer wrote Natorp in 1917 that notwithstanding the fact that the superficial cohesiveness of the Marburg School continued to decrease, the more each tried to head his own way, the more they would approach one another in their problems and tasks. This, Cassirer said, is the best and surest confirmation of their bond (*Zusammenhang*) they could hope for. (ECN 18: 1-1-1917)

Even though Cassirer's philosophy of symbolic forms is said to have represented the greatest challenge ever for the Marburg School, such threads were not posed to the Marburg School from the outside but were understood as challenges arising from within neo-Kantianism itself.[157] For such reasons, Cassirer nonetheless took himself to be a neo-Kantian throughout his carrier. While being in exile in Sweden he wrote: "I accept the label in the sense that all my work in theoretical philosophy presupposes the methodological foundation set out by Kant in the *Critique of Pure Reason*." [158] Like Kant himself had stressed continuously and Natorp repeated in his spirit, philosophy should be understood as a method, namely as "philosophizing".[159]

[156] See: Natorp 1912. Cassirer quotes Natorp in Determinismus: DI: p. xxiv.
[157] Ferrari 2009 p. 307.
[158] Cassirer 1993 pp. 201-202.
[159] Natorp 1912 pp. 196-197.

PART II

PHYSICISTS’ RECEPTION

7 INTRODUCTION

With the developments build upon Max Planck's discovery of the elementary "quantum of action" in 1900, physics entered into an irreducible state of self-reflection. In contrast with the electrodynamic view of light as a continuous wave, Planck's analysis of the radiation of black bodies forwarded the idea of light as discrete quanta who's energy is proportional to the frequency f by $E = hf$, where h is Planck's constant. The idea of light quanta, photons, provided an important basis for Einstein's analysis of the photo-electric effect in 1905, the emission of electrons from many metals when shining light on their surface. Whereas classical theory predicted that an electron would simply "gather" from the light the amount of energy it needed to be emitted, Einstein's analysis explained that the emission depended on the frequency of the light, i.e. the energy of the individual light quanta, and not in the intensity of the light or the total energy of the beam. These developments gave rise to the so-called wave-particle duality of light. Einstein's formula $E=mc^2$ had in a way expressed that we could no longer take part in a speculation about the ultimate substance of physical reality, asking if it is best characterized as energy, matter or electromagnetic radiation instead of focussing on the lawful interrelations between these concepts. Likewise, quantum physicists had to investigate how the conflicting conceptual structures of waves and particles were interrelated.

Instead of simply asking which "stuff" ultimately constitutes objective reality, the debate was now confronted with questions about the specific preconditions of the process in which objective knowledge can be established at all. Besides the characteristic wave-particle duality and the indispensability of descriptions characterized by an essential trait of discontinuity, quantum mechanics also contrasted with classical physics when it became clear that not all physical quantities can simultaneously have a precisely defined value. Moreover, this meant that we can only predict the future of micro-phenomena statistically. As was recognized by Werner Heisenberg, Max Born, Erwin Schrödinger, Niels Bohr and many others, the new atomic phenomena forced physicists and philosophers alike to earnestly reflect on the old foundations of physical knowledge. Also Cassirer was of the opinion that physics cannot any longer neglect the obligation of epistemological reflection. (DI: p. 129) Whereas before one could still argue for a realistic "viewpoint from nowhere" and the complete redundancy of an epistemological awareness, he said that this time no path any longer lead "back to that 'naive realism' which used to be recommended as the natural and adequate standpoint for physics." (DI: p. 131)

Central in the debates ensuing from the new quantum physics was causality. This was particularly the case in light of the fundamental statistical nature of micro-phenomena. The "uncertainty principle", also referred to as the "indeterminacy relations", appeared to lead to a view on reality which is in some sense intrinsically "indeterministic". In comparison with classical physics, or even relativity theory, causality could no longer be presupposed in a straightforward way. Moreover, quantum mechanics had allegedly dethroned it. This was claimed centrally by Max Born and Werner Heisenberg in 1927.[160] As will be discussed in chapter 10, others argued that causality had to be taken up in a more general principle of complementarity that restricted its application.[161] The following statement expresses how for Cassirer physical theory affected or perhaps even provoked philosophical research:

> *[I]n the transition to new sets of problems in scientific knowledge, the old concepts cannot simply be taken over but require in each case a fresh determination and interpolation in order to be applicable without contradiction. Thus even when we adhere to the general causal principle, we must first consider, in progressing to the phenomena and problems of atomic physics, how this principle can be applied under the changed conditions so as to do justice to its general function—so that it teaches us how to obtain a definite empirical concept of what occurs. This goal cannot be forcefully attained by means of a dogmatic assertion; we must be directed by experience itself when establishing empirical concepts. If experience shows that there are definite, precisely definable limits to our observation, then we may not arbitrarily transgress these limits in our empirical formulations of concepts. Rather we must give our causal judgments such a form as to remain compatible with them, so as to respect the new conditions which are now indicated for the application of causal thinking. This, it appears to me, was the way adopted by quantum mechanics.* (DI: p. 127)

The endeavour to clarify the meaning of the empirical limitations in the application of the general causal principle provoked many philosophical questions. Physics revealed certain empirical limits in the formulation of what Cassirer called “causal laws”. More generally, Cassirer said, philosophy was concerned with what he called the “principle of causality”. Like “spatiality”, as discussed in part I, the principle of causality was understood by Cassirer as an “empty” transcendental principle that guides the actual contents of empirical laws. Cassirer defined his generalized principle of causality as the a priori presupposition that “the phenomena of nature are not such as to elude or withstand in principle the possibility of being ordered”. (DI: p. 60) As such, causality is an absolute invariant of experience, Cassirer argued. Like the pure idea of “spatiality” is applied in both Euclidean and Riemannian geometry, this meant that all causal laws or empirical laws of nature are an “application” of one transcendental principle of causality. Quantum mechanics invited us to do justice to its “general function”, as Cassirer put it. In turn, such critical reflection may add to the credibility of the knowledge.

In part I it was explained that Cassirer was not primarily concerned with nature itself or as it is presented by physical theory. Rather—and this is was at times only a subtle difference—Cassirer wanted to know what conditions physical knowledge must satisfy in order to be accounted for as genuine knowledge in the first place. Cassirer centrally claimed in *Substanzbegriff und Funktionsbegriff* (SF) in 1910 and again in *Determinismus und Indeterminismus* (DI), published while he was exile in Gothenburg (Sweden) in 1937, that in

[160] Born 1927 p. 241, and Heisenberg 1927 p. 197. See also the discussion between Riezler (1928) and Fleck (1929).
[161] See: Bohr 1927.

physics the category of "substance and attribute" had been superseded by theory of relativity and quantum mechanics.[162] The individual elements of the theory had lost their priority over the theory as a whole and this meant that modern physical research was propelled by extra-theoretical "substantial evidence" but by the "ideal forms" (*Formidealen*) of a totality of experience and the unity of thought.

The category of substance and attribute, or of "thing and property" if you will, lay at the core Kant's philosophy as conditions for the possibility of both normal everyday experience and scientific experience.[163] The ancient assumption of underlying substances, whether we can know them or not, was typical for Aristotelean logic and Aristotelean metaphysics, and as we have seen the category had also been deeply entrenched in classical mechanics. Nonetheless, it was superseded by developments in modern formal logic, mathematics and the natural sciences. Already with relativity theory the relation between thing and property was not clear anymore because the measured properties like length and mass strictly depended on frame of reference. Objectivity, Cassirer said, ensued from the laws of coordinate transformation and the general covariance of the laws of nature and not from a correspondence to external things. Cassirer attempted to make way for an orientation in which the law-abiding character of experience in general would be central. This would also centrally be the case in his formulation of the principle of causality.

7.1 Objectivity for Cassirer

As a preliminary to the discussion on Cassirer's principle of causality, I shall here first consider the role and function for Cassirer of such a priori principles in establishing objectivity. Cassirer did not locate objectivity some sort of property of the laws of a theory to correspond to nature. Like for Kant, the general search of epistemology (*Erkenntniskritik*) was for a "shared reason" or a "shared world".[164] As Cassirer had expressed in his letter to Moritz Schlick, this shared reason or universal logos is seen in the principle of the "unity" nature which captured for Cassirer the true synthetic a priori element of modern science. (ECN 18: 23-10-1920) The strive for unity was the focal point of Cassirer's "structural" kind of objectivity and was centrally expressed by what he called "the objective determinateness of the method of experience". (SF pp. 321-322) Cassirer's view did not change in the decade and a half leading up to the publication of *Determinismus*.

---

[162] As Cassirer noted, the inadequacy of the concept of substance for modern physics was also acknowledged by mathematicians such as Hermann Weyl in his book *Was ist Materie?* (1924). Later, in 1941, also Weizsäcker suggested, in a sense very much like Cassirer, that the concept of substance had become superfluous with the arrival of quantum mechanics. See: Weizsäcker 1941a p. 193. See also: Weizsäcker 1941b.

[163] See for instance: Torretti 1999 p. 128. Although I will not discuss the claims made in Roberto Torretti's book, this source will provide us with some important footholds on the concepts of causality and determinism.

[164] Daston & Galison 2007 p. 262

Cassirer held that scientific thought makes sense because it is guided by a priori "rules of logic", or regulative "rules of pedagogy" such as causality.[165] (DI: p. 80) Put differently, scientific objectivity is established for Cassirer by the guidance of "those universal elements of form, that persist through all change in the particular material content of experience." (SF p. 268) A welcome side-effect of this approach was, that it explained the "peculiar changeableness … that is manifest in the content of scientific concepts of objects." (SF pp. 303-304) As Gottlob Frege and David Hilbert had expressed, "any theory can always be applied to infinitely many systems of basic elements".[166] Theories are functional-relational wholes, valid for any domain of experience in which the axioms of the theory are satisfied. It is not necessarily determined how the empirical concepts refer to the objects of experience. That is to say, questions such as what is matter or what is electromagnetism are usually left unanswered by the theory as it only expresses structural dependencies between those concepts.

Concerning quantum mechanics, for instance, questions about the essence of the atom or the essence of the quantum mechanical wave function are irrelevant as long as the empirical interconnectedness of knowledge is safeguarded and we make sure not to be guided by "mood or caprice" (*Laune oder Willkür*) but by a definite rule; "as long as insight into strict and precise relations between observable magnitudes is regarded as the only goal." (DI: p. 152) Therefore, the historical continuity and unity of science cannot be based on the assertion that science always speaks about the same objects. It is rather granted by invariant methodological principles and it was in this sense that Cassirer hoped to develop a "critical" and "*universal invariant theory of experience*." (SF p. 268) Like his teacher Hermann Cohen, Cassirer stressed in a truly Kantian fashion that a theory is objective when its concepts and judgements form a coherent systematic unity.[167] Notwithstanding the purely *ideal* status of such a final systematic unity and the temporality of what seems to be an ultimate stage of knowledge, the strive for unity regulates empirical and mathematical theorizing and grants it its objectivity: "This law [of progress] is the ultimate criterion of 'objectivity'." (SF p. 187)

Different scientific theories always presuppose a common ground in a universal scientific reason established by the guidance of universal a priori principles. Objectivity cannot be warranted by "relative" empirical a priori principles or concepts such as Newton's laws, the constancy of the speed of light, Euclidean space or the Riemannian manifold, because these principles often turn out to be in conflict with one another. We need at least some "absolute" a priori principles that allow for a common stock of meaning. Even though our formulations of the principles of reason may never attain a final status, we are in need of some generalized principles of which we can reasonably say that they are absolute. In contrast with Hans Reichenbach's account of the "relativized a priori", Cassirer held that some principles have no empirical consequences. Constitutive a priori principles, which determine or affect the appearance of the objects of the theory, clearly evolve over the course of history. For Cassirer,

[165] Heis presents a daring chart that collects the a priori elements of Cassirer's scientific epistemology. Although the validity of the regulative-constitutive and absolute-relative status Heis ascribes to them can often be questioned on the basis of Cassirer's writings, the tentative overview can be a welcome aid. See: Heis 2014 p. 13.

[166] Frege 1980: 29-12-1899. See section 3.2.3 for an explanation of this point

[167] See for instance SF 322.

in contrast, the "highest" principles do not constitute the object of the theory but merely regulate the laws of the theory. Even though the regulative a priori is not apodictic and our formulations of them must be in accordance with the developments of the theoretical sciences, philosophical progress is made on Cassirer's view as the universally invariants of experience progressively become synthesized into more comprehensive versions.[168]

Likewise, the task was set to approach the new theories as advancements based on their precursors. Cassirer endeavoured to think of science as one single enterprise that encompasses both Euclidean space and non-Euclidean spaces, both special relativity and general relativity, and both classical mechanics and quantum mechanics.[169] It is enlightening to repeat here a passage in *Determinismus* where Cassirer extensively quoted *Substanzbegriff und Funktionsbegriff* to highlight that contemporary developments in atomic and the new quantum theory confirmed the view that he had defended a decade and a half earlier:

> *To know a content means to make it an object, by raising it out of the mere status of givenness and granting it a certain logical constancy and necessity. Thus we do not know "objects" as if they were already independently determined and given as objects—but we know* objectively, *by producing certain limitations and by fixing certain permanent elements and connections within the uniform flow of experience. The concept of object in this sense constitutes no ultimate limit of knowledge. ... The "thing" is thus no longer something unknown lying before us as a bare material, but is an expression of the form and manner of conceiving.* (SF pp. 303-304) (DI: p. 137)

Cassirer's objectivity was thus not characterized by a coincidence with an independently pre-determined object. As also explained in part I, it was rather understood that an objective theory only progressively leads us to the object by what Cassirer described as a permanent "fixing" of "elements and connections within the uniform flow of experience" in "*function* of objectivity". (Ibid.)

[168] See for instance: Heis (forthcoming a) pp. 10-11.

[169] Cassirer may have felt that the violations of the Kantian category of "substance and attribute", the relation of causality to "the principle of continuity" and the demand of the "entire determination" of physical reality, both discussed below, appeared to pose a direct threat to the objectivity of quantum mechanics. Additionally, Niels Bohr argued generally that classical mechanics could only be derived from quantum mechanics in a statistical way, giving only the probabilities of classical outcomes. The transition from statistical laws to dynamical laws is wholly different from the transition of, say, curved space to flat space in general relativity. (See for instance: Bohr 1927 p. 64) Because Cassirer, nor the physicists in their commentaries, did not problematize the approach of classical mechanics as an *approximate* or *limiting* case of quantum mechanics, I will not pursue the issue any further. Important to note here is that for Cassirer, theories provide rules as to how new theoretical elements could be taken up in the future when new facts, or "anomalies" if you will, come to light. Therefore, the "durability" and "flexibility" of a theory—its capabilities to adapt—were according to Cassirer fundamental traits of objectivity as theories are perpetually challenged to take up both new and old facts.

7.2 Causality and determinism

Cassirer argued that the generalized "principle of causality" must be understood as the absolute requirement of "conformity to law".[170] It is what Cassirer had formulated in his letter to Moritz Schlick as the summit of the synthetic a priori: the "law-abiding character of experience in general" (*der Gesetzlichkeit der Erfahrung überhaupt*). As such, Cassirer suggested that it is identical to the unity of nature and that these principles are to be regarded as the purest expression of reason, of "logos" itself. (ECN 18: 23-10-1920) Causality as conformity to law was an expression of the universal requirement of the unity of nature and hence an objective method of experience. The principle was in no way based upon statements of objective reality. Rather, judgements of objective reality are based on causality: "Objectivity or objective reality is attained", but only "because and insofar there is conformity to law—not *vice versa*."[171] (DI: p. 132)

However, causality has more commonly been defined as the lawful dependence of one occurrence, the effect, on another occurrence, the cause. In this sense, we are dealing with what Cassirer called "causal laws". Such laws can be defined to hold between occurrences, phenomena, events, objects or entities.[172] They express a temporal relation in which one occurrence, the effect, is necessarily preceded by another, the cause, in accordance with a necessary rule.[173] This was also Kant's definition of the causal law.[174] As such, it is often said that causal processes have something to do with dynamics, that is, with forces between atoms and molecules or the lines of force of electromagnetic fields. Additionally, as we will see in what follows, causality, and also determinism, have often been connected to the possibility of prediction and the theoretical tools with which scientists predict physical processes.

Cassirer, in contrast, forwarded causality strictly as a "regulative" methodological principle. For him, the principle of causality did not determine *how* the objects of science occur in appearance. Rather, causality meant for Cassirer *that* we can establish universal rules that allow us to relate cognitions to other cognitions in a lawful manner. Likewise, Kant had already differentiated the principle *that* every natural event must have a cause from its particular instantiations: the causal laws to which the objects physics obey. Somewhat more vigorously than Kant, Cassirer defended that the requirement of causality is posed independently of the further limiting conditions of space and time. (DI: p. 163-164, 167) These constraints were for

---

[170] Cassirer was at pains to show how this reliance on nature's "conformity to law" was already found in the writings of many historical figures like Galileo Galilei, Christiaan Huygens and Hermann Helmholtz.

[171] See also: Sundaram 1972 p. 48.

[172] These definitions are for instance almost identical to what Henry Margenau in his preface to *Determinismus* held to be Born's definitions in *Natural Philosophy of Cause and Chance* (1949). Born was one of the principle physicists to claim that the causal law had lost its application. See: Born 1927.

[173] See for instance: Torretti 1999 p. 131.

[174] Kant 1998 A195-196/B240-241. On the law of causality see generally Kant's "Second Analogy of Experience": B233ff. See generally on this topic: Allison 1983. See also: Torretti 1999 p. 130. Torretti says that the understanding of causality in the Second Analogy was more or less in line with our everyday causal inquiries.

Kant a result of the demand of the "schematization of causality".[175] Classical causal laws introduce a connection with continuous time in order to perceive cause and effect as a continuous succession of the manifold of intuition. Cassirer argued that this demand was violated by quantum mechanics.

As will be discussed below, Cassirer radicalized Kant's differentiation by arguing that in light of the ineliminable discreteness of phenomena revealed by quantum mechanics, the a priori demand of continuity had to be given up. He concluded that even though quantum mechanical observations do not obey the forms of continuous space and time, the relations laid down by them are nevertheless strict, unambiguous and necessary and therefore causal. This line of reasoning was also followed with respect to the statistical interpretation of the quantum mechanical state and Cassirer's interpretation of "statistical causality": The outcomes of measurement are only "statistically determined", as Born called it.[176] Nonetheless, the statistical relations are universally valid. Instead of dynamical relations, quantum mechanics was now dealing also with statistical relations as the fundamental explananda of observable phenomena. They allow us to explain nature in an orderly and thus causal fashion.[177]

Because causality has often been directly linked to the question of determinism, the two concepts were sometimes used interchangeably. Cassirer provided a sensible reason for this conflation, for he said that determinism should be treated as the thesis of "universal causal relations".[178] For understanding Cassirer's purposes this doctrine can also be called "cosmic determinism", since the claim is usually put forward as a speculation about the possibility of the perfect and infinite prediction of the course of the universe. Determinism appeared in Cassirer's writing centrally as a speculative conclusion or intuition concerning man's general worldview (*Weltanschauung*).[179] As we will see below, Cassirer discussed the thesis centrally in light of his discussion of Laplace's Demon and in his discussion on morality and the free will.[180] As such, he usually approached determinism as an "unconditional" statement, that is, as a metaphysical statement that does not take into account the indispensability for cognition of a priori requirements, centrally causality. When not limited to the conditions of knowledge of a

---

[175] Krois 1987 p. 113.

[176] Born 1927 p. 241. (See footnotes 230, 284, 223)

[177] It is in this respect interesting to note that the word "cause" is derived from the Latin causa which was primarily used in the sense of "legal case". Yet, the Greek equivalent αἰτία, which was Aristotle's word for "cause" commonly meant "responsibility", usually in a negative sense. Αἰτία has also been translated as "explanation". See: Torretti 1999 p. 130.

[178] Margenau claimed this in his preface of *Determinismus*. Margenau was a close colleague and disciple of Cassirer. Cassirer had proposed to collaborate in the preparation of a bibliography and an appendix on the developments of the problem of causality after 1937. The appendix was aimed to bring the question of causality up to date, but unfortunately, Cassirer past away a few months after his proposal in 1945.

[179] See for instance: DI: p. 122.

[180] The doctrine of universal causal relations is also related to physical reductionism, the doctrine that all experience can in principle be explained by physical entities and relations. Cassirer also clearly steered away from this view.

"finite intellect", determinism almost becomes an article of faith, something one can believe about the "eventual nature of things", Cassirer said. (DI: pp. 23-24)

Instead, as will be discussed below, Cassirer argued for a "critical determinism", a much lighter claim, not about nature but about the conditionality of scientific reason. Seeing that for Cassirer causality was a universal presupposition of reason, or a formal concept or axiom of knowledge as such, it becomes clear that a connection with the doctrine of determinism as "universal causal relations" could be re-established in a critical sense. Critical determinism implied for Cassirer an awareness that in science there is *no* intelligible object corresponding to the immediate and non-sensible intuition that tells us that for every occurrence in nature there is an antecedent event, *ad infinitum*. (DI: pp. 23-24) A more critical determinism can be established when seeing that the principle of causality is not a statement about the nature, or physical objects or events, but a universal presupposition about the interconnection of statements of law and measurement, saying that they can and should be so constructed to form *one* coherent unity. Also, I will discuss why a notion of indeterminism could on Cassirer's view not contribute to the further development of knowledge. To know means to achieve a determinate content in thinking. The presupposition of a fundamental indeterminism contradicts this fact. This explains Cassirer's leniencies toward determinism.

More commonly, however, determinism has been defined as the following statement: If the universe is deterministic, then every occurrence results necessarily from antecedent events governed by the laws of nature so that if a system has a well-defined state description, we can logically derive all past and future states of the system. This thesis is sometimes called "causal determinism". This definition has also often been connected with the perfect prediction of matter in motion, as also seen in Cassirer's attack on the Laplacean demon.[181] Generalizing this definition into a statement that does not involve matter in motion, we can also say that determinism is a statement about mathematical formalisms, saying that our differential equations have unique solution.[182] Put differently, determinism says that the behaviour through the course of time of a physical system is in accordance with a system of differential equations that in virtue of their mathematical properties have one *unique* solution. Like the statement of classical determinism, the result is that if the value of all physical quantities are exactly given for a certain instant in time, the state of the system is *fixed* for all times.

These latter formulations of determinism are satisfied by the continuous and completely fixed evolution in time of the quantum mechanical state as described by Schrödinger's equation. However, they are violated by the measurement of the observable properties of quantum systems. In virtue of the laws of quantum mechanics, we cannot simultaneously establish precisely defined values for all observables. Although Cassirer clearly addressed the violation of determinism in this sense, he hardly disentangled this issue from the satisfaction of

[181] See: Van Strien 2014 p. 25. This understanding of determinism as "the doctrine of *necessity*", it is argued by Ian Hacking, traces back to the 1850s in France. (Hacking 1990 p. 153-154). (See footnote 202)

[182] Torretti 1999 p. 132. See also: Van Strien 2014. Torretti calls this the "physicists' principle of causality" but immediately adds that it is in effect a "principle of determinism" quite foreign to ordinary causal thinking. (p. 131) This shows, again, why determinism and causality have often been discussed in one breath.

determinism by Schrödinger's equation. The discussion in Cassirer's *Determinismus* clearly involved both separate points of view but hardly opposed the two explicitly. Cassirer did not discuss the "collapse" of the wave function proposed by Heisenberg in 1927. Nor did he discuss the two processes of collapse and Schrödinger evolution as identified by John von Neumann in 1932.[183] *In nuce*, this "problem of measurement" can be summarized as the rupture between the fact that the formalism of the theory only allows us to calculate multiple possible outcomes of measurement, whereas in actual measurement we can only establish one value. Besides another short remark in chapter 10, I will not pursue the matter of the collapse of the wave-function any further.

Causality and determinism can thus be treated as sufficiently distinct, the former being a statement about necessary relations between events over the course of time—or in Cassirer's case, the relatedness of laws and phenomena as such—the latter being a statement about the uniqueness of solutions of differential equations. Yet, both ideas were linked to the possibility of prediction. In that sense, determinism should be seen as an amplification of causality: If nature is "indeterministic", the possibility of full and complete prediction is excluded. However, if relations are not causal to begin with, the possibility of prediction collapses completely. It was for such reasons that Cassirer treated causality as a more fundamental requirement than determinism.

7.3 The failure of substance-concepts

In what follows, I will first discuss Cassirer's principle of causality and the reactions of physicists in their reviews and letters. Cassirer's position was somewhat unorthodox and at odds with what physicists had often meant with causality, as his physicists commentators objected. In the subsequent chapter, I will discuss Cassirer's attitude toward determinism and indeterminism on the basis of suggestions made by physicists. Even though the difficulties with causality and determinism were in the centre of attention, Carl Friedrich von Weizsäcker was the only commentator to identify clearly that according to Cassirer the essential problem posed by quantum mechanics did not primarily concern the rupture with classical causality. Quantum mechanics did imply a failure of the Kantian category of relation "cause and effect", but of a failure of the category of "substance and attribute".[184] (DI p. 235: p. 189) The central issue for Cassirer was the departure from the metaphysical views connected with classical logic discussed in part I.

Scholars have urged that Cassirer's views are in tune with the Copenhagen interpretation.[185] Somewhat like Cassirer, both Bohr and Weizsäcker distanced themselves

---

[183] See: Neumann (1932) *Mathematische Grundlagen der Quantenmechanik* (Berlin: Springer).

[184] Weizsäcker 1937. The third category of relation "community", or "reciprocity", is not discussed in *Determinismus*. See also: DI: p. 131.

[185] For example: Sundaram 1972 p. 47. Margenau (in his preface to *Determinismus*) and Schmitz-Rigal also believe that Cassirer's point of view is in line with the Copenhagen interpretation. (Schmitz-Rigal 2002 p. 311) Schmitz-Rigal even claims that in many moments Cassirer's "open-holistic model of knowing" resembles the ideas proposed by the founding fathers of quantum mechanics, centrally Bohr's and Heisenberg's. (p. 351) While Sundaram argued that Cassirer attempted to do justice to Bohr's complementarity as a fundamental epistemological principle, it will turn out that this was not the case.

from what could be called a picture theory of truth and meaning in favour of a performance and goal oriented, more functional account of the perceptual and conceptual order in physics. Moreover, as I will show, some of Weizsäcker's ideas as brought forward in 1941 were very close to what Cassirer wrote in *Determinismus* in 1937. Cassirer took much interested in the principle of complementarity as put forward by Bohr, one of the leading figures of what in the 1950s became known as the Copenhagen interpretation. However, Cassirer did not accept Bohr's complementarity as a fundamental principle. I will very shortly compare Bohr's thoughts on the principle with Cassirer's in chapter 10. Finally, I will argue shortly why Cassirer was also driven to write against the introduction of a notion of indeterminism because of concerns with the nature of practical reason.

7.4 Compliments

Before commencing with the critique on Cassirer's treatment of the concept of causality and his stance toward indeterminism, I will here first shortly discuss some of the many positive responses Cassirer received. Like many well-known physicists at that time, Einstein received a copy of *Determinismus*. Cassirer's accompanying letter remarked that in philosophical circles, "odd" (*seltsame*) conclusions are often drawn from the "physical indeterminism". (ECN 18: 8-2-1937) Notwithstanding the odd conclusions, Cassirer added, the question of causality was just as central to epistemology as it is to physics and needs to be investigated carefully. Einstein responded that he had studied the book carefully. His response was full of praise, stating that he didn't know what to admire more, Cassirer's keen mind, his art of presentation or his deep insights.[186] (ECN 18: 16-3-1937) Cassirer was generally perceived as an eloquent writer.[187] Hans Pettersson gloriously introduced Cassirer as a "master of penetrant analysis", saying that no one was better qualified to unravel the "highly complicated knots, arising from the almost hectic development within theoretical physics."[188]

The philosophers Carlo Antoni and Ernset Nagel were even more laudatory. Reading *Determinismus* physicist could expect a "cold shower" when speaking all too quickly of indeterminism, Antoni said. Antoni suggested that philosophers were best suited to deal with the ongoing questions of determinism, causality, and the ancient philosophical concept of the

---

As in the review published by Hans Pettersson, for instance, Cassirer was generally bid to do better justice to the remarkable consequences of contemporary physical speculations on complementarity in a continuation of his "illuminating exposé". (Pettersson 1937)

[186] However, Einstein spent only a few sentences on the book itself, the rest of his long letter discussed his version of the famous incompleteness theorem of quantum mechanics, a problem Cassirer did not directly deal with in his book. It is known that Einstein was unhappy with the presentation of the theorem in the article published together with Boris Podolsky and Nathan Rosen in 1935. As a result, Einstein attempted to distance himself from it and sent many letters to friends and colleagues to explain his version of the argument. (See footnotes 218 and 323)

[187] In the review of Antoni for instance it was said that Cassirer "masterfully dominates the scientific literature". (Antoni 1938) Born extensively complimented Cassirer on the breadth of his point of view and the depth of his knowledge, in particular of physical matters. This latter quality was rare for a philosopher, Born added. (ECN 18: 19-3-1937)

[188] Pettersson 1937.

atom. Cassirer solidly cooled down the romanticisms of physicists and showed once again how physics had never been content with common sense and had needed philosophy from the beginning.[189] Nagel wrote in his review that Cassirer set "standards of maturity which few physicists themselves attained in the *obiter dicta* on it."[190] In passing, Nagel found, physicists already had made remarks on the problems that the second law of thermodynamics and quantum mechanics in general had posed for the causal law, but Cassirer's systematic questioning were a rarity to be treasured.

Born reported to be deeply impressed by *Determinismus*.[191] He was amazed to see a non-positivist philosopher concerned with physical research and fully agreed with Cassirer's thesis of the epistemological primacy of the functional-relations of natural laws instead of the entities that the laws combine. (ECN 18: 19-3-1937) Moreover, in his published "Waynflete Lectures" of 1948, Born stated to embrace Cassirer's strict demarcation of ethics and physics.[192] I will discuss this matter of ethics in the final chapter. Max von Laue, who wrote Cassirer at least three letters, reported to have read *Determinismus* eagerly and intensively and that he was delighted about the fact that so many physicists had expressed their thoughts on his writings straight away. (ECN 18: 23-3-1937; 4-4-1937) Laue also applauded to Cassirer's historical perspective and acknowledged that such a perspective implies a certain contingency, that is, that ideas can easily change over time and have indeed done so in the past. (ECN 18: 26-3-1937)

In the first major review that appeared, Weizsäcker applauded to Cassirer's great success to start a discussion and highlighted the relevance of the book for philosophically minded scientists. Also, Weizsäcker complimented Cassirer on his pleasant style of writing, his sophisticated historical approach, his exposition of the "Laplacean spirit" (*Laplaceschen Weltgeistes*) and his subtle analyses of different forms of causality.[193] Heisenberg reported to have been delighted by many of Cassirer's formulations and in particular to see that an exchange between philosophy and physics was again possible. (ECN 18: 24-3-1937) That we can then learn many important things from the "border area" between philosophy and physics has been shown afresh by Cassirer's book, he said. However, what exactly has happened in modern physics, Heisenberg remarked, could only be seen and understood in ten or fifteen years, when the current enterprise of atomic physics would be completed and we arrive at exact formulations of the decisive laws for the core of the atom.

---

[189] Antoni 1938.

[190] Nagel 1938 p. 230.

[191] The German edition of *Determinismus* used for this study at the Max Planck Institute for the History of Science was Born's private exemplar. It is a first pressing and is inscribed and signed by Cassirer, stating: "*Mit den besten Grüßen*". Its cover is worn out and the whole artefact almost falls apart. This suggests that Born read the book thoroughly. Also, Born wrote that he regretted not to have known *Determinismus* when he held his lecture, probably referring to the lecture he gave upon becoming a fellow of the Royal Society of Edinburgh: *Some Philosophical Aspects of Modern Physics*.

[192] Born 1949 pp. 207-208.

[193] Weizsäcker 1937.

8 CAUSALITY

What all the historical views on causality share, Cassirer concluded upon his historical investigation, is that the "essential characteristic of causality consists in the general requirement of order according to law, not in instructions as to how this order can be discovered and followed through in detail." (DI: p. 163) For such instructions we have to consider specific causal laws, Cassirer said. But because causal laws can always be imagined otherwise, as the history of causality showed, causal laws must be seen as contingent. The historical evolution of causality showed for Cassirer that the causal concept embraces "a good many problems and a wealth of dialectical tensions." (DI: p. 168) Let me here highlight some of the historical variety contained in *Determinismus*. Without considering how Cassirer's claim was inherently connected to his interpretation of the history of physics, his formulations of the principle of causality would appear hollow and vain. Although for more systematic reasons, this is what Schlick suggested regarding Cassirer's principles of "spatiality", the "unity of nature" and the "law-abiding character of experience" in 1921.[194] (ECN 18: 23-10-1920)

8.1. A long history short

I will start with a most basic view on causality as it is identified with the mechanistic notion of "contact action". This was famously done by for instance David Hume. In what could be called Hume's "billiard ball" picture, causality is essentially a temporal relation. Causes are assumed to happen *earlier* than effects, like antecedent momenta of billiard balls determine their resulting momenta in accordance with a necessary rule. Sceptical of this necessity, however, Hume said that there is absolutely nothing *in* experience that guarantees us which out of the hundreds or infinitely possible events results from the cause or causes. When we see, for instance, a billiard-ball having a velocity in one direction and moving in a straight line toward collision with another, there is no conclusive proof that the ball will not deviate from its resulting trajectory as prescribed by the laws of mechanics. Therefore, Hume saw that causality cannot be said anymore to hold for "things in general". (DI: p. 14-15) Hume nevertheless affirmed that knowledge of physical events is generally possible and to explain this possibility, he concluded that the causal law can only be a psychological "habit" or "custom".[195]

8.1.1 Laplacean determinism

After Hume, others followed who extensively argued against the idea of causality as based on matter in motion. In order to understand properly the different meanings of the concept of causality and the criticisms on Cassirer's treatment of it, we shortly have to leap forward to the question of determinism in respect to a famous formulation given by Pierre-Simon de Laplace in 1814. Determinism and causality were intricately linked concepts. Notwithstanding the many

[194] Schlick 1921 p. 326.

[195] See Hume's *A Treatise of Human Nature* (1739) and *An Enquiry concerning Human Understanding* (1748).

compliments, Weizszäcker for instance stated in his review that he would have liked a more thorough treatment of classical causality which he took to be causality as he said Laplace had formulated it.[196] Usually, Laplace's formulation is associated with the concept of determinism in the sense of the perfect and unique prediction of all the future and past states of the system.[197] This statement of determinism is met almost constantly in discussion on causality, for it seems to be the direct ontological implication of the epistemological principle of causality: If in a physical theory, every occurrence is necessarily preceded by another in accordance with a universal causal rule, say Newton's laws, then we can uniquely predict the future and the theory is deterministic. It is in this reasoning assumed that necessity of the rule also means that it produces *one* necessary result.

Cassirer continuously referred to Laplace, who is often credited with providing the first definition of determinism.[198] He argued that Laplace's formulation was famously lifted "out of its long oblivion" by the physician and physiologist Emil du Bois-Reymond, who fiercely attacked determinism in the 1870s.[199] What was known as "Laplace's demon", Cassirer said, is an embellishment of the formula which was introduced only later by Bois-Reymond.[200] (DI: p. 4) Laplace had imagined an intellect which would at a certain moment know all the forces of motion in nature and all the positions of all nature's items. [below I also added premise: know all initial velocities] If the intellect's analytic powers are vast enough and we regard the present state of the universe as the effect of its past, Laplace reasoned, nothing in the future nor in the past would be uncertain for it. Herewith, Cassirer wrote, Laplace provided a "metaphor" that allows for a reflection on the nature and limits of the scientific intellect. And indeed, the formulation is a *possible* definition of determinism, Cassirer granted Bois-Reymond, for Laplace said that a perfect prediction of mechanical matter in motion is thinkable and consistent. However, Cassirer vigorously defended, Laplace never raised this metaphor to a general epistemological principle.

The function of Laplace's reasoning was essentially to show the difference between the concepts of "certainty" and "statistics", and not between determinism and indeterminism, Cassirer argued.[201] (DI: p. 4) Determinism, Cassirer held, is usually a cosmological thesis and

---

[196] Weizsäcker 1937.

[197] See: Van Strien 2014 p. 25.

[198] Usually with reference to Laplace's *Essai philosophique sur les probabilités* (1814).

[199] See: Bois-Reymond's *Über die Grenzen des Naturerkennens* (1912).

[200] In *Essai philosophique sur les probabilités* (1814), as Cassirer noted, Laplace had spoken of an "intellect" or "understanding" (*une intelligence*).

[201] (See footnote 234) Contrary to Cassirer, and in line with du-Bois-Reymond, Marij van Strien takes Laplace's argument to be a definition of determinism. (Van Strien 2014) Also Torretti (1999 p. 93-94) and Ian Hacking (1990) take this stance. Strien argues that Laplace's determinism was based on the principle of sufficient reason: "everything must have a reason or a cause" and the principle of continuity: "no cause can engender an effect suddenly". She argues furthermore that Laplace's determinism was based on the principle of sufficient reason in the sense of "production": for everything there must be a cause that brings it about. (p. 31) In short, Van Strien concludes, Laplace's argument came down to the following: "[T]he principle of sufficient reason implies that there is a continuity between states, and this implies that the state of the universe is the cause of the state at the next instant,

is wholly different from the concept of complete certainty. We can in principle attain complete or maximal knowledge even in a universe which would be presupposed as “indeterministic”. Moreover, even when we suppose that nature is fundamentally ordered by statistical laws, this would not be enough ground to assume a fundamental indeterminism of reality. This argument against indeterminism will be further explored below.

Strictly holding on to the classical or mechanical world picture had led scientists like Bois-Reymond to tout the idea of the bankruptcy of causality and determinism. We are unable to grasp full knowledge of all initial matter and force, let alone produce predictions that are perfect, he reasoned. In doing so, Bois-Reymond gave common currency to the phrase *ignoramus et ignorabimus* (we do not and will not know).[202] However, Cassirer argued that accepting Laplace’s formula unconditionally as a cosmic revelation of reality is a “false self-gratification of reason” typical of metaphysics. Not all scientists would be prepared to make such a leap of faith. Yet, upon closer examination it becomes clear that principles like Laplace’s have provided epistemological guidance in the physicists’ attempt to reveal nature’s workings. Cassirer concluded therefore that we should not ask whether specific causal laws are universally valid as formulations of the more general principle of causality, but try and understand in light of contemporary knowledge how they functioned merely as “imaginary foci”, determining what we regard as true and false, objective and subjective. (DI: p. 24)

8.1.2 Perfect prediction

An understandable misunderstanding occurred with the enormous success of Newton’s theory of “matter in motion”, Cassirer wrote. Newtonian laws and states together with the idolisation of the “perfect” prediction of the “Laplacean demon” came to be seen as the essential elements of causality. (DI: p. 65) Even without considering quantum mechanics or statistical mechanics, Cassirer found that causality, in this Newtonian-Laplacean sense as the certain prediction of future positions and momenta on the basis of the possibility to fully know the initial conditions was way too narrow and restrictive. Moreover, as was discussed above, these formulations should be connected with the concept of determinism. For Cassirer, the causal problem was a more fundamental issue. Instead of discussing causality as prediction, Cassirer maintained, we are better off inspecting the general formalism of the calculus of infinitesimals and see how it satisfied causality in the sense of the absolute requirement of a conformity to law.

---

and in this way it implies determinism.” (Van Strien 2014 p. 39) Hacking critically examined Cassirer’s thesis. Against Cassirer’s account he argues convincingly that determinism as the doctrine of *necessity* arose in the 1850s in France and not in 1872 with Bois-Reymond’s lecture in Germany. (1990 p. 153-154) (See footnote 182) Yet, scientific determinism as *necessary* causal relations was already proposed by Kant in 1781, Torretti argues. (1999 chapter 3) We will obviously not attempt to raise here a discussion on who was right, Cassirer, Hacking or Torretti. Still, it is important to see, as Hacking notes, that Cassirer was not convinced by Bois-Reymond’s depiction of Laplace because his physiological stance was, like that of his teacher Helmholtz, generally tainted by what could roughly be formulated as a psychologistic attempt to reduce all that is knowable to abstractions of sense-impression or events in the brain, even a priori concepts. Such an approach was perpendicular to the transcendental status of a priori principles.

[202] Bois-Reymond’s *Über die Grenzen des Naturerkennens* (1912).

The assumption of a general mathematical “lawfulness” (*Gesetzlichkeit*) of nature had been highly productive. Moreover, Cassirer defended, the pioneers of the mechanistic world view themselves, Kepler, Galileo, Descartes and Leibniz, did not so much work from the principle that all happenings in nature are based on the contact action of matter in motion. Their thoughts had proceeded from the conviction of the Platonic ideal of the identity of mathematics and nature.[203] (DI: p. 12-13) Although strongly venerating this highly productive ideal, Cassirer found, as we will see, that it was an inadmissible hypostatis to believe that our concepts were at once mathematical and metaphysical. (DI: p. 24)

8.1.3 Uncertainty and causality

Much later with the development of quantum theory and the establishment of the full theory of quantum mechanics there proved to be an irreducible uncertainty in phenomena on atomic scales of length. Heisenberg therefore claimed in 1927 that our knowledge of the present is inherently incomplete.[204] I will here shortly sketch why. In Heisenberg’s formalism called “matrix mechanics”, the observable properties of nature, centrally position and momentum and energy were represented by algebraic entities called “operators”. When these algebraic operators are applied to the descriptions of quantum mechanical states they provide us with possible outcomes of measurement. Instead always having one outcome as a result of our calculations, as it was the case in classical mechanics, we now typically have multiple.

It quickly turned out that not all of Heisenberg’s operators “commute”. In effect this meant that the simultaneous application of the operators of momentum and position result in an irreducible uncertainty.[205] Whereas it had classically been assumed that all material objects simultaneously have a precisely defined position and a precisely defined momentum, this could no longer be said of quantum states described by Erwin Schrödinger’s wave equation. This equation replaced Newton’s laws of motion. Moreover, physical states are represented by wave-like entities which are the solutions to Schrödinger’s equation. Let’s shortly take a moment to explain what this implied.

The quantum state can be described as a normalizable wave packet in terms of, say, both space and wavelength transformable by Fourier analysis. A wave-packet can have a perfect resolution in terms of wavelength by an indefinite spread over space, but only when paying the price of a total loss of resolution in terms of position. In other words, the sharper the definition of in terms space and time, which comes down to a “contraction of the wave packet”, that is, a clear localization in space and time, the less clearly defined are respectively the wavelength and frequency of the state.[206] Such a trade-off, quantum mechanics discovered, also appeared between descriptions in terms of space-time and the description in terms of momentum and energy.

---

[203] Also Heisenberg is said to have recognized this Platonic ideal in Einstein’s theory of relativity. See: Jammer 1989 p. 344.

[204] Heisenberg 1927 p. 197.

[205] A quantum state cannot be prepared in terms of a basis of eigenvectors of both operators.

[206] Jammer 1989 p. 369. See also: Bohr 1927 p. 50.

In effect, we could no longer perfectly predict the future of “matter in motion”. We could no longer derive single future or past events by following a necessary rule. With respect to events on atomic scales of length, this radically announced the doom of the Newtonian-Laplacean causality. (DI: p. 123) Moreover, there even turned out to be precise limits to the physicist’s certainty as shown by the “uncertainty principle”, put forward most famously by Heisenberg. Due to the fundamental wave nature of all atomic phenomena, the product of the uncertainty in the measurement of position “Δx” and that of momentum “Δmv” can never be reduced below a certain value proportional to the elementary “quantum of action”, Planck’s constant h. Heisenberg concluded therefore that the causal law was proven wrong for good. It becomes empty and lacks application because “in the precise formulation of the causal law: ‘If we have exact knowledge of the present, we can determine the future’, not the consequence but the antecedent is wrong”.[207]

Cassirer did not agree. It has often been noted that with uncertainty formulated as the lack of antecedent knowledge, Heisenberg’s uncertainty appears to be arbitrary. It seems that we might as well presuppose that our knowledge of nature can always increase and that quantum mechanical uncertainty is therefore not fundamental.[208] The uncertainty relations might then in principle be overcome. The hope was set for undiscovered variables of nature that could, at least in principle, be known with full precision so that the concept of causality based on the idea of the perfect prediction could still be maintain. But as long as causality was not elevated to a more general principle of cognition, this hope was in vain and causality could not be saved, Cassirer argued. In fact, Heisenberg’s formulation of causality was identical to Laplace’s formula. As such it was too imprecise and narrow to have any universal pretence in the sense of a neo-Kantian epistemology. Cassirer reasoned as follows: Causality cannot depend on the empirical possibility of perfect predictions because the possibility of making predictions as such universally presupposes that nature is causal. As Hans Pettersson comprehensibly formulated it in his review of *Determinismus*: “Without causation, prediction obviously becomes impossible, but the reverse is not at all true.”[209] Only when the call for a more general formulation—the formal requirement of the lawfulness of experience—was honoured could causality be upheld.

In his review of Cassirer’s book, Pettersson formulated furthermore how the logical form of all causal laws was actually improved by quantum mechanics. Every causal statement, Cassirer said, takes on the form the category of the pure implication “if x, then y”. (DI: p. 41, 124) They explain one thing as the reason or the cause of another. Now, uncertainty does not only creep in at the side of the antecedent but also in the consequent.[210] Therefore, Pettersson suggested, the form of causal laws could in light of the uncertainty relations also be stated as “if $x \pm \Delta x$, then $y \pm \Delta y$”.[211] Even if uncertainty arises exclusively in the initial conditions, this does

[207] Heisenberg 1927 p. 197.
[208] Jammer 1989 p. 349.
[209] Pettersson 1938.
[210] See also: Krois 1987 p. 111-112.
[211] Pettersson 1937.

not imply the falsehood of the derived consequences on the basis objective laws, let alone the falsehood of the general logical form.

8.2 Kant's demand of continuity

Einstein vividly explained in a popular article he wrote for *The Times* in 1929 that strictly speaking, the successes of the wave theory of light were already breached with Newtonian physics. It appeared that Newton's kinematic forces could be explained dynamically as the results of microscopic electric fields. Also, Newton's suggestion that light was a particle with special properties was rejected with the help of Maxwell's electrodynamics. Einstein concluded that the dissatisfaction with the dualism between fields and particles so typical for quantum mechanics was already announced by this pre-history of a philosophical battle for supremacy between the principle of continuity and the demand of taking into account the "discontinuous elementary structures" of nature.[212]

The historical dialectics between continuity and discontinuity is by no means straightforward. Even though Cassiser was not entirely clear on the significance of the violations of continuity in allowing for a broader formulation of causal laws, I believe that the issue was central and shall here sketch why. Already with the advent of the field theories of Faraday and Maxwell it became clear that nature might be not solely composed of matter and forces but also of fields and electromagnetic waves. The typically mechanistic view that nature is composed solely of matter that Hume had trusted upon in his rejection of causality gradually became outdated when physics increasingly became "demechanised". With the physics of fields, Cassirer said, a more mature form of physics arose. The "contact forces" as established by Faraday's and Maxwell's laws of the electric field transformed the older mechanical substance-theory radically. (DI: p. 168) "A field is not a 'thing'", Cassirer said, it is rather a "system of effects". (DI: p. 178) Faraday's concept of "lines of force" pushed aside the concept of persisting substance, because the individual electron, for instance, "'exists' only in its relation to the field, as a 'singular location' in it." (DI: p. 178) The electromagnetic fields enclosed physical relations that were clearly causal but were hardly understandable in terms of the old mechanical contact. More importantly even, Maxwell's laws were not based upon the existence of particles in motion but on electrical and magnetic fields interacting with a finite instead of infinite speed. (DI: p. 168) This meant that nature obeys a certain "locality", which was also a central principle of relativity theory.

In contrast to the instantaneous effects of Newton's gravity as action-at-a-distance, locality demanded that objects can only be influenced directly by their immediate surroundings. Ever since its introduction, Newton's action-at-a-distance encountered the sharpest criticism. Cassirer explained that Faraday had been able to overcome Newton's conventional instantaneous force by re-establishing a relation to continuous space. Also Kant had strongly emphasized the demand of continuity. For Kant, the principle was connected to the pure intuition of time and could be formulated as the demand that "no cause can engender an

[212] Einstein 1929.

alteration suddenly".[213] (DI: p. 162) For Kant, this meant that there cannot be allowed a time which is the smallest. His formulation of continuity stemmed from Leibniz, for whom the principle played a central role in the foundation of differential calculus and stated that "all transitions in nature are gradual" and changes can only take place through "all the intermediary stages."[214] This principle was intrinsically connected to the formulation of the laws of physics.

Although Kant strongly confirmed their kinship, he also made clear that there was no direct relation to the pure category of causality itself, which could be formulated as the regulative principle that "everything that happens has a cause".[215] Only in light of the empirical application of the causal concept, that is, the classical wielding together with intuition, did the principle of continuity immediately present itself as a further limiting condition of causality. Such and similar constraints were for Kant a result of the demand of the schematization of causality.[216] The schematization is based on common characteristics or rules by which we can make sure that the formal concept is connected to the senses. More precisely, the condition of continuity must be associated with time, Kant said. The classical causal law introduces a connection with time by which the schemata of cause and effect are allowed to be intuited as a "succession of the manifold".

8.2.1 Letting go of continuity

Instead of overthrowing the principle of causality as such, quantum mechanics overthrew the further restriction of continuity by showing that the relation between continuity and discreteness must be understood in an entirely different way. It had classically often been presupposed that in nature, every whole can be broken up into components until we arrive at the ultimate indivisible elements of nature. Classical mechanics allowed for an instantaneous force of gravity, yet the calculus of infinitesimals was strictly continuous, i.e. effects could be engendered suddenly. On the other hand, the mathematics of fields and waves, which, are continuous as intuition would suggest, could not be combined with in a straight forward way with the concept of discrete particles, i.e. localized entities in space and time. Also, both electrodynamics and relativity theory relied on a strictly localized understanding of events, a demand that is violated by quantum mechanics. The troubled history of continuity implied that we are better off disconnecting it from the concept of causality, Cassirer concluded.

Not only could light be represented by the concept of corpuscular, as Planck and Einstein had shown, the wave-particle conflict became ever more acute with the discovery that matter also had properties characteristic of waves. Yet, Cassirer argued, such troubles in no way need to lead to a sceptical *ignorabimus* because "always in the past such conflicts have been shown to have not only a negative but also an eminently positive significance; far from erecting insurmountable barriers to knowledge, they prove to be its most important incentives." (DI: 174) The main result for Cassirer was that he had to disentangle Kant's linkage between

[213] See for a comparison with Kant: Kant 1998 A189/B232ff. See on Kant's treatment of Newton's action-at-a-distance, which he nevertheless accepted, for instance Friedman's *Kant's Construction of Nature* (2013).

[214] Van Strien 2014 p. 37.

[215] Cassirer quoted: Kant 1998 B357.

[216] Krois 1987 p. 113.

continuity and causality and grant that already on epistemological grounds, the claim of continuity was too strong for reason and limited it to a particular physical worldview. In giving up the absoluteness of the possibility of dissecting natural phenomena into parts *ad infinitum* and the condition of the "immediate spatial proximity between cause and effect", (DI: p. 167) i.e. locality, Cassirer suggested that "a new concept of the wholeness of natural occurrence is formulated." (DI: p. 173)

On the one hand, continuous functions reigned supreme with Schrödinger's wave equation. Understanding matter as represented by Schrödinger's waves contradicted the demand of strictly on "localized" individual events. Furthermore, Schrödinger had associated the solutions of his wave equation with a continuous distribution of charge and current which represented the electrostatic and magnetic properties of the atom. This lead to the intuitively "strange" conclusion that every individual material point occupies at every instant all positions of space. (DI: p. 173) On other hand, Heisenberg's matrix mechanics introduced an algebra based on discrete numerical quantities, dispensing with every support of the continuum of real numbers. (Ibid.) Also, in Bohr's model of the atom and his explanation of the Balmer series—which incorporated a strict discreteness in the possible orbits of an electron around the nucleus—electrons could make immediate leaps from one energy state to another. It became clear that as effects are transferred discontinuously over space, nature "leaps from one location to another without touching the intermediate space."[217] (DI: p. 167) The possibility to make "jumps" was not just a conventional solution but deeply entrenched in nature.

Bohr also said that both Schrödinger's formulation and Heisenberg's matrix mechanics involve "a neglect of the finite velocity of propagation of the forces claimed by relativity theory."[218] The quantum postulate, symbolized by Planck's quantum of action, attributes to every atomic process an essential trait of discontinuity.[219] Because of the fundamental uncertainties in micro-phenomena, any treatment of the observation of nature must deal with an "uncontrollable interaction" due to the exchange of at least one elementary quantum of action, Bohr said.[220] In sum, this implied according to Cassirer that, again, causal relations could no longer be said to necessarily have a continuous form.[221] (DI: p. 162-163) In the demanded "specialization" of the principle of causality that is indispensable for its empirical use, we may now refer to the "pure form of discrete numbers." (DI: p.166)

As a result of what was in essence the decoupling of causality and space-time, causality faced a severe trial, Cassirer explained. Quantum mechanics blew up the classical

---

[217] In a sense, this seemed to be a relapse toward the infamous action-at-a-distance. In relation to quantum mechanics, this is now referred to as "non-locality". Quantum mechanics violates causality when it is interpreted in a strictly local sense as was shown by the Einstein-Podolsky-Rosen article (1935) in which it was defended that quantum mechanics was therefore an "incomplete" theory. There is, however, little to no indication that Cassirer had any intention to get involved with these views. Moreover, Cassirer did not problematize the non-local implications of the theory. (See footnote 187 and 323)

[218] Bohr 1927 p. 57.

[219] Bohr 1927 p. 52.

[220] See besides Bohr 1927: Bohr 1948 p. 313.

[221] Krois 1987 p. 113.

demand of continuous space and time so violently that causality was expected to be blown up with it. However, "we have to liberate [the causal demand] from the limiting conditions which have hitherto interfered with it; we have to formulate it in such a manner that it no longer appears as a continuous bond between the 'things' of our sensuous space and 'events' in our sensuous time." (DI: p. 163) This put an end to Kant's formulation of the causal law—the "everyday causality" which states that every occurrence is always preceded by an event in time—which is an enormous intellectual sacrifice, Cassirer said. After first discussing Cassirer's treatment of statistical laws I will more elaborately go into his alternative formulation of causality.

8.3 Causality and statistical mechanics

To be able to properly appreciate the responses of the physicists discussed below, it is important to realize that causality was already a hotly debated topic in science at least up until the mid-1930s.[222] Central in Cassirer's treatment of causality was the theory of classical mechanics, in particular in relation to the ideas of Ludwig Boltzmann and Franz Serafin Exner. Both Boltzmann and Exner had claimed that laws of probability can have an equally objective standing as the usual dynamical laws. They thereby infused the ongoing debates on the status of causality with a wholly new dimension, namely a certain sense of indeterminism. In what follows, I will were possibly focus only on causality and leave Cassirer's comments on indeterminism for the time being.

Statistical mechanics generally dealt with problems of describing and predicting the behaviour of systems of large amounts of particles, for example in the thermodynamic processes of diffusion and heat transmission. Notwithstanding its successes, it appeared that statistical laws were not fundamental as they did not have an objective basis in the relations between individual objects but dealt with large scale collections of particles. Whereas classical mechanics was deterministic in the sense that it uniquely predicted the future or the past, statistical mechanics was not. Even though strict averages necessarily come about in the infinite limit of large scale phenomena, every possible event will occur when the scope of observation is extended over sufficiently large periods, no matter how improbable it is. (DI: p.77) For that reason, statistical laws do not have the property of "indwelling necessity" that is so characteristic of dynamical laws.

Boltzmann's law of entropy therefore introduced a notion of natural law that was alien to the mechanical picture. Boltzmann tried to argue that his law of entropy should be given an equal rank with the dynamical laws.[223] However, as Cassirer expressed, the laws of probability enjoyed a poor status in relation to deterministic cosmology. Already with the introduction of Boltzmann's law it had become clear that statistical laws do not have the same "dignity" as the

---

[222] Born 1927 p. 241, and Heisenberg 1927 p. 197. See also: Riezler (1928) and Fleck (1929). Michael Stöltzner claims that the causality debates extended across roughly three decades, from Exner's 1908 inaugural lecture, declaring statistical laws to be the comprehensive genus instead of dynamical laws, until around 1935 with the discussions on the "completeness" of quantum mechanics ensuing from the paper written by Einstein, Podolsky and Rosen (EPR). (Stöltzner 2011 p. 10)

[223] By considering collectives of atoms as the basic entities, Boltzmann invoked "a priori assumptions to justify probability distributions for the atoms". (Stöltzner 1999 p. 87)

"normal" dynamical conformity to law.[224] This threatened the status of causality as the possibility of necessary rules between single causes and effects.

Exner tentatively argued against the grain that statistical laws are of a higher order than dynamic laws and that they include them as a special case. (DI: p. 81) Exner said that classical dynamical laws could be seen as a special case of the more comprehensive laws of probability. By taking the side of the less fortunate laws, Cassirer found, this was a heroic attempt to get rid of the dualism between dynamical and statistical laws. Others were unwilling to jettison the older causality that easily and held that a determinism based upon the presupposition of dynamical laws still sufficed. Planck was a "mild" proponent of the latter option and held that only strict dynamical laws satisfy the intellectual drive (*Erkenntnistriebes*).[225] (DI p. 108: p. 86) Generally, it could still be maintained that physical theory could in principle also predict the behaviour of individual particles. The unexpected prevalence of fundamental statistical laws also for single atomic phenomena that was brought forward by quantum mechanics, however, gave rise to ever more serious doubts about the possibility of prediction.

Paul Forman famously argued in 1971 that the "wild" controversies regarding causality came to a conclusion with quantum mechanics when an intellectual hostility toward causality motivated physicists to support a philosophical indeterminism by the end of the 1920s.[226] But, in light of Cassirer's publication of *Determinismus* in 1937 it makes sense to claim that the causality controversy raged on even after the "quantum revolutions" in the mid-1920s. It is said that Forman's thesis is unable to address some core aspects of the causality debate because he did not properly assess the interactions between philosophical and scientific commitments in the context of Weimar Germany and interwar Austria.[227] Our case of the reception of Cassirer's *Determinismus* by physicists is precisely such a cross-disciplinary interaction. It shows that even though in the 1930s physicists may have supported a philosophical indeterminism, the philosopher Cassirer still managed to cause a small stir. At least, the physicists who responded to Cassirer's book were provoked to challenge his ideas. For Cassirer, the developments of statistical mechanics, and particularly quantum mechanics, meant that a broader and more stable notion of causality was needed, a notion which enabled him to deal with quantum mechanics as a fully causal theory, an interpretation which, in effect, leaned toward determinism.

---

[224] "Appearances certainly provide cases from which a rule is possible in accordance with which something usually happens, but never that the succession is *necessary*; therefore, a *dignity* pertains to the synthesis of cause and effect that cannot be empirically expressed at all, namely, that the effect does not merely follow upon the cause but is posited through it and follows from it." (Kant 1998 A91/B124) We will discuss this remark below in light of Cassirer's function interpretation of causality.

[225] Cassirer explained that for Planck "only strictly dynamical laws satisfy the requirements of our urge for knowledge while every statistical law is basically inadequate [*unbefriedigend*] because it offers an indefinite answer in place of a definite one". (DI p. 108: p. 86) See also: Stöltzner 1999 p. 107; and Mills 2014 p. 37. Planck's view is discussed shortly below in 9.2.2.

[226] See generally: Forman's 'Weimar culture, causality, and quantum theory: adaptation by German physicists and mathematicians to a hostile environment' (1971).

[227] Stöltzner 2011 p. 1.

8.4 Statistical causality

Because with quantum mechanics also microscopic and sub-microscopic phenomena turned out to be predictable *only* for large numbers of events, typically seen in the decay of radioactive isotopes or the transitions of electrons between orbits around the nucleus, some physicists argued that causality had lost its application.[228] Cassirer attacked such views in *Determinismus* and claimed that statistics and causality are not mutually exclusive. The opposition is rather to be found between statistical and dynamical laws, but both these kinds of law are causal. Modern atomic sciences revealed for Cassirer that besides a "mechanical causality" we should also be take into account a "statistical causality". (DI: p. 116)

Like Newtonian mechanics, electrodynamics, statistical mechanics and relativity theory, also quantum mechanics dealt centrally with a conformity to law, Cassirer said. The statistical statements of quantum mechanics are strict and by no means indefinite, as also Born had hinted.[229] Born emphasized, both in his article and in a letter to Cassirer, that usually the use of statistical methods is justified by an incomplete knowledge of the initial state (*Anfangszustand*) but that in quantum mechanics we seem to be dealing with physically necessary probabilities, that is, probabilities that not depend on a lack of knowledge.[230] (ECN 18: 19-3-1937) Quantum mechanics demonstrated that statistical laws can attain full-fledged explanatory power as they express necessary connections between the observable phenomena of the theory. For Cassirer this was reason to argue that statistical laws are causal. We only have to give up the demand that these relations always allow for unique solutions, that is, reject the thesis of determinism as perfect and complete prediction.

Besides a statistical causality, the possibility comes to mind to take into account a notion of probability as an a priori condition for physical knowledge. Born remarked for instance that in the history of quantum mechanics the concept of "a priori probabilities" (*Warscheinlichkeiten*) had played a crucial role.[231] However, Cassirer maintained that probability could not be a fundamental principle. As Cassirer had explained to Schlick in 1920, probability (*Warscheinlichkeit*) could for him only be meaningful and definable under the condition of a much more general concept like truth (*Wahrheit*). (ECN 18: 23-10-1920) We find a similar idea in *Determinismus*. The two different modes of description, dynamical and statistical, rely on more fundamental concepts like truth and causality.[232] Cassirer argued that neither statistical causality nor dynamical causality is to be regarded as the comprehensive genus because both are based upon the same presupposition of the lawfulness of experience.

---

[228] This was claimed most pointedly by Heisenberg and Born. See: Heisenberg 1927 p. 197 and Born 1927 p. 241.

[229] Born 1927 p. 241. Born said that physical processes are not "causally determined" but "statistically determined". (See also footnotes 177, 327 and 284)

[230] Born 1927 p. 238-240.

[231] Born 1927 p. 240.

[232] What Cassirer had in mind with these "two modes of description" will be discussed shortly below in the section on the possibility of indeterministic theory.

8.5 Cassirer's functional principle of causality

Before discussing the critique of the physicists, I will here elaborately discuss Cassirer's principle of causality, its relation to Kant's and its status as a pure concept of a universal reason. Cassirer found that of all the various definitions of causality given by Kant in the *Critique of Pure Reason*, the most satisfying and comprehensive formulation of causality was perhaps that in experience "everything that happens has a cause".[233] This formulation was so satisfying according to Cassirer because it represented also for Kant "nothing but a direction for the formulation of definite empirical concepts."[234] (DI: p. 127) The principle of causality is expressed by "the *search* after ever more general laws" and it is "a basic feature [*Grundzug*], a regulative principle of thought [*unseres Denkens*]". (DI: p. 60) While keeping a close eye on new theoretical developments, Cassirer suggested that the principle of causality should be completely deprived of all its ontological import. Because causality should hold whether we think for instance of Newtonian matter in motion, the curved spacetime of accelerating objects, the wave-like nature of matter or the statistical interpretation of the wave equation in quantum mechanics, we should "suspend" all its positive content. The general principle must remain completely "empty" with respect to what kinds of causes will be considered.[235]

In light of these demands, Cassirer formulated causality as the universal presupposition that "the phenomena of nature are not such as to elude or withstand in principle the possibility of being ordered". (DI: p. 60) The principle is given a priori in the sense that it is an invariant presupposition. Shorter formulations of Cassirer's causality are: the presupposition of an intelligible orderliness in nature; an orderliness according to law; that which is law-like (*das Gesetzliche*) or lawfulness (*Gesetzlichkeit*). (DI: pp. 62-63, 163) As Kant had continuously emphasized, the pure concept of causality is synthetic a priori knowledge. It is distinct from the more specific, synthetic a posteriori and contingent causal relations. I will shortly explain what this meant for Kant.

For Kant, the causal laws of nature are necessary rules "in accordance with which certain events always follow on certain appearances."[236] Hume had also understood causality in this sense. However, Hume sceptically contended that there is absolutely nothing in experience that guarantees that causal relations are necessary. Indeed, Kant said in the *Prolegomena*, when seeing causal laws merely as "subjective connection of perceptions" causality seems to have no ground.[237] We could say that there is no "logical ground" to assume the necessity of the laws of

---

[233] Cassirer quoted: Kant 1998 B357. (See footnote 202) Clearly, this formulation of causality reminds one of the ancient "principle of sufficient reason", famously espoused by Leibniz. A crucial importance between causality and sufficient reason is, however, that sufficient reason is related, in particular by Leibniz, to the question of "final causes" and what I have called cosmic determinism. (Strien 2014 p. 31) Cassirer steered away from the identification with sufficient reason probably because the principle had been imbued with metaphysics throughout the history of philosophy. It could easily be misinterpreted as a *property* of nature itself instead of a *condition* for experience, a condition that holds for "things" instead of "cognitions".

[234] Cassirer hereafter quoted Kant's *Critique*: 1998 B357. See also: B163.

[235] See for example: Kant 1998 A668/B696.

[236] Kant 1998 A195-196/B240-241.

[237] Kant 1783 § 29.

nature. Yet, causal laws are experienced as universal relations and therefore as necessary. It remains to be so that in the relations laid down by valid causal laws, the effect *always* follows. So even though there is no logical reason for causal laws being thus and not otherwise, in experience they nevertheless possess what could be called a "*real* ground".[238]

Experience, Kant's reasoning continued, "is possible only by means of the representation of a necessary connection of perceptions".[239] Mere subjective perceptions are converted into objective experience by a necessary process of unification which is always limited by certain pure ideas and based on them.[240] Appearance itself can never provide the necessity of for instance the succession of time that is laid down in classical causal laws. Time is therefore a transcendental condition, Kant said. Kant also said that because of the necessity characteristic of causal relations, "a *dignity* pertains to the synthesis of cause and effect that cannot be empirically expressed at all".[241] Instead of accounting for the possibility of objective knowledge of nature by accrediting causality, like Hume, with a meagre psychological status of "custom" or "habit", Kant vigorously defended that it must be seen as a transcendental idea. So already for Kant, and also for Cassirer, the transcendental unity of knowledge, necessary in establishing objectivity, implied a conception of causality in which for instance the laws of Newtonian mechanics were more specific empirical instantiations of an *absolute* synthetic causal demand.

Cassirer said that even though Kant was right in locating causality among the regulative principles of reason, he still was sometimes inclined to speak of it as holding for things and events, rather than purely for cognitions. Nagel noted in his review that for Cassirer the assumption that causality must be a statement about the interconnection of *natural objects* "engenders an agnostic scepticism as to the possibility of knowledge."[242] Cassirer had nothing to say in support of such a naturalistic conception of causality like a causality based on the often rejected Laplacean kind of determinism of matter in motion. Cassirer, Nagel summarized, is determined to present causality as a principle concerning the "form" of our knowledge of the laws of nature. Causality is a "regulative principle for the construction of the science of physics, and it requires physical inquiry to be so conducted that it aims at a *logical system* of physical knowledge."[243] As such it harboured the possibility of doing proper science, because it presented a general and definite methodological structures.

As an a priori condition of experiment and knowledge, causality doesn't directly lead to scientific experiments testing the universality of lawfulness as such. (DI: pp. 62-63) This would be a category mistake, treating causality as an a posteriori law of nature. The principle was for Cassirer instead an invariant of empirical thought. Like Kant had said, it "shows how in regard to that which happens we are in a position to obtain in experience any concept (*Begriff*) whatsoever that is really determinate."[244] (DI: p. 127) An important paradox arises, Cassirer

[238] See: Kant 1998 B357.
[239] Kant 1998 B218.
[240] See: Kant 1783 § 22.
[241] Kant 1998 A91/B124.
[242] Nagel 1938.
[243] Nagel 1938.
[244] Kant 1998 B357.

explained. Firstly, the principle of causality is *necessary* "because every individual empirical statement is based on it, and because it precedes all empirical judgements as a synthetic judgement a priori." (DI: p. 103) It is a *conditio sine qua non* of science. Secondly, it must be demonstrated to be valid for nature and restricted to it. (DI: p 59) The causal laws which it brings forth are *contingent* because "the whole of experience to which it refers and on which it has to base its justification" is given in a purely factual way and can always be imagined otherwise. (DI: p. 103) Thus, as Hume had convincingly showed, causality cannot be proven on the basis of experience itself. Nor can causality be derived from other concepts. In causal judgements it is therefore always presupposed that some "productive activity" of thought takes place. In sum, we must not only suspend all content in the formulation of the principle, we must also ask what we can demand of such a formulation and therefore carefully observe its content in physical theory.

Moreover, Cassirer added, causality is to be regarded strictly as a principle not as a law or a statement of measurement. Rather, it is a statement *about* the form of laws and measurements, a statement strictly about the methodology of science: "For us, the causal principle belongs to a new type of *physical* statement, insofar as it is a statement about measurements, laws and principles. It says that all these can be so related and combined with one another that from this combination there results a system of physical knowledge and not a mere aggregate of isolated observations." (DI: p 60) This lead Cassirer to discuss the problem of *plurima ex paucissmis*, that is, the problem of induction. This problem is unresolvable and is raised to the epistemological aim of comprehending and describing the greatest number of phenomena with the fewest number of determining factors, Cassirer said. (DI: p. 70) Herewith, Cassirer said, physicists implicitly take recourse to the only one valid scientific counsel: trusting *the inadequate* and acting upon it will turn it into a fact:[245] (DI: p. 63)

> *It is true on the other hand, however, that we have no other warrant for* [causality its] *applicability* [Anwendbarkeit] *than its success. If we could live in a world in which every atom differed from every other and no regularity would be perceivable, then in such a world our intellectual activity* [Denktätigkeit] *would necessarily come to rest. But the investigator does not reckon with such a world. He trusts in the intelligibility* [Begreifbarkeit] *of natural phenomena, and every particular inductive inference would be untenable for him, if this universal trust did not form its basis.*[246] (DI: pp. 62-63)

---

[245] This counsel was generally taken from Wilhelm Helmholtz', Cassirer said.

[246] With this depiction of causality as the epistemological need for orderliness, Cassirer was deeply indebted to Helmholtz' conception of causality. It is the *first product* of the attempt to conceptually grasp nature. Put differently, Cassirer explained, causality is the postulate that our experience displays what Helmholtz had called *das Gesetzliche* (that which is law-like) or put differently, an "orderliness according to law". (DI: pp. 62-63) "What we call 'cause' can be understood and justified only in this (Helmholtz's) sense" of a general order. (DI: p. 62) That causality is the first product of reason did not mean that the cognition was prior to all other cognition but simply that it is universally presupposed in every valid judgement concerning "facts". See for instance: SF p. 357. See on Cassirer's rejection the a priori as an *idea innata*: DI p. 59.

What is constant in every causal judgement is that it contains not so much a prediction of future events but that it carries the promise of future cognitions: it is aimed at the abundance of knowledge which will only later unfold itself. It is in this sense that causality is, in Platonic terms, "pregnant of the future".[247] (DI: p. 65) For Cassirer, the principle was an expression of reason as the "ordering toward [*Hinordnen*] a freely anticipated imaginary focus".[248]

Against announcements that the new quantum mechanics endangered the possibility of a physics that is fully causal, Cassirer herewith attempted to "save" causality. We can now say that Cassirer's causality principle was satisfied by quantum mechanics since the presupposition of lawfulness remains in place. Put differently, this was so because all statements of the theory—centrally Heisenberg's matrix mechanics, Schrödinger's wave mechanics and the statistical interpretation of the relation to observation—are strict, definite and necessary. As such, causality was detached from the issue of determinism as the uniqueness of the outcomes of measurement, which will be discussed below. As a consequence of the generality of his approach, however, Schlick's critique seemed to apply once more. Cassirer's formulation of the principle of causality turned out to be identical to the law-abiding character of experience in general, mentioned in his letter to Schlick in 1920. (ECN 18: 23-10-1920) With this principle, Schlick had maintained, Cassirer made no contentful assertion since it could neither be confirmed nor rejected by scientific theories.[249]

8.6.1 Criticism: The conservation of energy

In his review of *Determinismus*, Pettersson took note of Cassirer's high regard of the law of conservation of energy as a possible candidate for the principle of causality, as proposed by Wilhelm Ostwald. In light of this "energy principle", Pettersson regretted, Cassirer did not deal with contemporary attacks against this principle and in effect against the principle of causality. These attacks were perhaps even "more devastating" than those he had refuted.[250] Pettersson highlighted that according to present-day developments, α-particles can "traverse" or "transcend" a potential barrier that was classically insurmountable and thereby seriously

[247] "Pregnancy" is a Platonic concept also used by Cassirer in the *Philosophy of Symbolic Forms*. Krois highlights Cassirer's theory of meaning as "symbolic pregnancy". (Krois 1987 p. 117)

[248] Schmitz-Rigal 2002 p. 362.

[249] Schlick 1921 p. 326.

[250] Pettersson 1937. Also Laue had doubts about the philosophical relevance of Cassirer's elaborate discussion of Ostwald's energy principle as a causal law. It was Ostwald's thesis that all physical events consist of changes in energy. But, Laue objected, this thesis was already contestable on physical grounds: "*Dieser Ostwaldsche Satz ist leider schon physikalisch recht anfechtbar*." (ECN 18: 26-3-1937) Laue provided a physical counterexample of a stone that is attached to a string and as a certain angular momentum. In this (ideal) situation, physical events clearly occur while both the kinetic energy of the stone and the potential energy of the string remain unchanged. However, Cassirer would have rejected out of hand the discussion of the energy principle as a candidate for the generalized principle of causality because it equates a substance with a function. Ostwald's thesis was of interest because also Bohr connected causality to the laws of conservation of energy *and* momentum and regarded his notion of complementarity as a more general statement which incorporated both causality and space-time. See sections I and II in Bohr 1927.

infringe the law of energy conservation.[251] Pettersson regarded this discovery as a contemporary infringement of causation and noted to be unconvinced of Cassirer's arguments. But, instead of taking it up for the energy principle as a candidate for causation, Cassirer *merely* stressed that the concept of energy had been remarkably constant over the course of time and remained to be of crucial importance also in quantum mechanics, as was for instance seen in Einstein's analysis of the photo-electric effect and Heisenberg's analysis of the Compton-effect.

Energy is itself not the true summit of causality but it leads us to it, we might say. "The representatives of strict energetics tend to merge the concepts of energy and causality [*Energiebegriff und Kausalbegriff geradezu ineinander aufgehen zu lassen*]; they claim that the causal concept has its only actual fulfilment and adequate physical representation in the concept of energy." (DI p. 144: 116) To give way to the tendency to equate the regulative causality of reason with the concept of energy (*Energiebegriff*) was for Cassirer a turn to metaphysics. It takes one a posteriori law and equates it with the a priori principle it satisfies, namely the presupposition that nature displays an intelligible orderliness according to law. It is precisely with the continuous reliance on these highly stable conceptual relations like the principle of conservation of energy that the principle of causality is implicitly "postulated and recognized". (DI p. 145: 117)

In quantum mechanics, the reliance on the energy principle has even taken on a more refined form. The Hamiltonian, which is the operator corresponding to the total energy of the system state, is closely related to the Schrödinger equation. It generates the time-evolution of the system state. Also, the Hamiltonian prescribes that the outcomes of a measurement of energy lie within a certain spectrum of integer multiples of Planck's quantum of action. This discrete character of energy does not put in question the validity of the law of conservation of energy. Moreover, one could refer to the Hamiltonian as providing inexact statements, but, Cassirer said, the discrete energy levels prescribed by the Hamiltonian principle are more precise than what could established in any measurement.[252] (DI: p. 118) For Cassirer, to repeat, the case of the conservation of energy only served to illustrate the "plasticity" of the causal principle, that is, to show how specific constitutive forms and causal relations and laws can change over time. (DI pp. 92-93: 73-74)

8.7 Criticism: Uncertainty and reality

Cassirer remarked that conclusions like Bois-Reymond's *ignorabimus* always presuppose the existence of a metaphysical "hard core of reality" that is inaccessible to cognition. I will here shortly illustrate Cassirer's view on this matter and then discuss a related comment made by Frank on the principle of uncertainty.

The new physics was intuitively paradoxical because the formalism effortlessly switches between the discontinuous attributes of particle and the continuous attributes of waves. Both conceptual structures apply to the same object of knowledge. But, one could ask,

---

[251] Pettersson 1937. "Tunneling", as it is called nowadays, is a direct implication of quantum mechanics.

[252] Cassirer referred for this statement to Schrödinger's 'Die gegenwärtigen Situation in der Quantenmechanik', in: *Naturwissenschaften*, 23 (1935).

we still do not know *what* exactly an atom is. Is matter ultimately constituted by point particles or by waves? As the result of a “dilemma that we face again and again throughout the history of physics”, namely that things are “posited to which nothing empirical corresponds”, we seem forced to assume an “obscure realm of being”, a “substantial core” of nature to which we have no access. (DI: p. 134) This substantialist viewpoint, however, leads directly to a fundamental agnosticism in which the “unknowable” becomes a presupposition of knowledge itself. (DI: p. 130, 149) But, Cassirer said, understanding knowledge on the basis of “the unknown” gets us nowhere.

On a substantialist view, we are always forced to acknowledge the existence of some kind of fundamental carrier, say, material, energetic or electrodynamic, without fully comprehending what that carrier would be. Properties of matter such as “solidity”, “rigidity” and “hardness” have been pushed further and further into the background with the advent of modern physics, first being “degraded” to properties for visualization and later to notions no longer determining the basic character of atomic theories at all. For Cassirer this mean that the metaphysical characteristics of the substantialist viewpoint had been replaced by a functional understanding. The tendency toward a direct hypostasis of theoretical concepts, the demand that there is necessarily something empirical that correspondents to them, makes knowledge impossible, because our separate intuitions are always in conflict. It always leaves knowledge with an unknown remainder and ends in a persistent *aporia*. Such scepticism was for Cassirer not in accordance with the overwhelming abundance and accuracy of scientific knowledge. Instead of constituting an *ignorabimus* or a rupture in rationality, Cassirer would probably have sided with Hilbert’s response to Bois-Reymond’s kind of scepticism: “*Wir müssen wissen—wir werden wissen!*” (We must know—we will know!)[253]

Yet, Frank wrote in his review that Cassirer’s critical attitude toward metaphysics was “not entirely consistent”.[254] In light of the uncertainty principle, Cassirer had spoken of a “physical being” (*physikalischen Sein*) as a “border” (*Grenze*) which is presupposed within the “process of physical knowledge” (*physikalischen Erkenntnisprozess*). Such talk is highly objectionable Frank commented. Presupposing a “real world”, Frank believed, was a characteristic fiction of a “school philosophy”, even when it is merely a border or a “limit”.[255] Frank also remarked this in his letter to Cassirer. (ECN 18: Frank 137. *Ohne Datum*, p. 176) Frank found that Cassirer was not able to correctly present the scientific meaning of the uncertainty principle. Occasionally when reading *Determinismus*, Frank said, we get the impression that quantum mechanics forces us to remain completely agnostic about the question what “the thing in absolute sense” is. He found that Cassirer’s idealistic formulations somehow

[253] Hilbert had written in 1900: “We hear within us the perpetual call: There is the problem. Seek its solution. You can find it by pure reason, for in mathematics there is no *ignorabimus*.” (Hilbert 2000 p. 412) Hilbert also declared this on radio in 1930. See: Hilbert 1930. Schlick also had his doubts about scepticism and said that “nothing harms inquiry so much as the pronouncement of an *ignorabimus*”. (Schlick 1918 p. 326)

[254] Frank 1938 pp. 77-78.

[255] Frank and Richard Mises argued for the abandoning of the old “triad of school philosophy”, referring to the traditional categories of space, time, and causality, and replacing them with what they thought were more suitable notions. See: Stöltzner 2009 p. 3.

make it sound as if quantum mechanics implied that behind the theoretical "world of relationships" between observations there lies "another real world", a world that we can never comprehend fully.[256] In doing so, Frank suggested, the book tended to discuss the existence of things beyond their relation to different experimentally realizable circumstances.

Indeed, Frank recognized that on the basis of the classical transcendental idealist conclusion of the *noumenal* thing-in-itself, quantum mechanics seemed to imply that there is no way to know if there ultimately exist entities that have both precisely defined positions and precisely defined velocities, violating the uncertainty relations. Frank found such an interpretation to be inacceptable, as he had also formulated in an article published in 1936.[257] Taking quantum mechanics seriously meant that instead we leave behind all talk of the real world as a border because such a property cannot be talked about in a scientific sense. Such talk was only a rest product of a "metaphysical idealism", a "school" type of philosophy that is being stripped down further and further, Frank believed.[258]

As was discussed, however, Cassirer radically denied talk of the existence of things outside of their empirical and transcendental conditional determinations. Seeing that all our access to the world is mediated by cognition meant for Cassirer, as Frank recognized, that quantum mechanics radically affirmed that instead of the "thingness" expressed by the theory, we now deal with a reliance on the "lawfulness" of experience and a structural kind of objectivity. Taking into account Cassirer's *Substanzbegriff und Funktionsbegriff* (1910), it would have become clear that the functional theory of knowledge prevented one from asking at all if there exists an inaccessible realm of more or less classical particles that have both precisely defined positions and precisely defined velocities. Also in *Determinismus* Cassirer put forward that "[t]here is no answer to these questions—unless the answer is that they cannot be asked in this form because they presuppose a situation which is not empirically definable for us." (DI: p. 179) Asking for classical particles doesn't make much sense to begin with since the lawfulness on the basis of which the empirical reality rests—the uncertainty principle—excludes the possibility. As I will explain in the next chapter, this argument was also related to Cassirer's attack on indeterminism.

8.8 Criticism: Historical excursions

Nagel formulated in his review that even though it was clear enough that Cassirer's causality could not be "'refuted' on grounds of sensory impression", it was not "simply a methodological resolution" either. Nagel did not single out Cassirer's causality as the idea of orderliness according to law. Nevertheless, he saw that for Cassirer, causality expressed an "absolute intellectual invariant to which there seems to be no alternative". Nagel noted the principle was strictly regulative and concerned the form and direction of knowledge instead of its content. However, Nagel concluded to remain a "good deal in the dark" with regards to the status of causality with respect to other regulative and constitutive principles of science, which was after

[256] Frank 1938 p. 77.

[257] Frank 1936 p. 11-12.

[258] Frank 1938 p. 77. But luckily, Frank highlighted, Cassirer usually satisfied the positivistic demands of credible philosophy and abided by clear statements that can be verified scientifically.

all the book's main.[259] Underlining more clearly the statement that causality is the presupposition of orderliness according to law, its relation to the unity of nature and knowledge, or even its possible relation to Leibniz' principle of sufficient reason might have elucidated what now indeed remained to be somewhat obscure.

Carlo Antoni—much like Schlick in his review of Cassirer's treatment of special and general relativity—came to criticize Cassirer's principle of causality by saying that it was so broad that it became identical to the idea of science itself, that is, Antoni said, to regularity and coherency.[260] Weizsäcker had a similar complaint. He concluded that the many rich "historical excursions" with which Cassirer attempted to provide each problem with the proper context gave the whole contemplation a "certain width and serenity".[261] Weizsäcker suggested that the ease with which Cassirer flew over the history of physics resulted in a particular flaw, namely the inability to rigorously treat the classical law of causality.

Weizsäcker recognized that, in contrast with the attitude of physicists, Cassirer was of the opinion that the principle of causality is being applied all the time as it universally regulates scientific knowledge. He cited: "*Der Kritische Kausalsatz enthält keine unmittelbare Aussage über die Verbindung von ‚Dingen' und ‚Vorgängen', sondern vielmehr eine Aussage über den systematischen Zusammenhang Erkenntnissen*". (DI p. 203:) Therewith, Weizsäcker explained, also statistical laws became bearable as being *merely* mathematical formulations, without harming the "causal thesis" (*Kausalsatz*) as such.[262] But, consequently—and here comes the problem—Weizsäcker asked:

> *darf ein Philosoph, der gerade das Erbe Kants bei der Deutung der neuen physik fruchtbar machen will, so leicht auf die engere Fassung des Kausalsatzes verzichten, die der klassischen Mechanik entspricht und an die Kant selbst geglaubt hat?*[263]

Indeed, Cassirer did not rigorously disproof more narrow formulations of the classical law of causality such as Laplace's demon. Teasingly, Weizsäcker stated that it was a great accomplishment for a philosopher to systematically question a closed system of convictions at all. Nonetheless, Weizsäcker implied, Cassirer could have done so in a more systematic fashion. Also Nagel noted that Cassirer seemed all too easily to do without Kant's original

---

[259] Nagel 1938.
[260] Antoni 1938.
[261] Weizsäcker 1937.
[262] Weizsäcker 1937.
[263] Weizsäcker 1937. According to John Michael Krois, Weizsäcker misses the irony of Cassirer's remark in the foreword to *Determinismus* in which he expressed to expect objections like these. (DI: p. xxiii) (See section 6.2) Saying that Cassirer was as a Kantian not warranted to draw non-Kantian conclusions, implicitly relied on a narrow conception of Kant's work as a "system of ideas" rather than a methodologically tentative project. (Krois 1987 p. 114) Moreover, Cassirer was in fact at pains to show how his generalized principle of causality was already contained in some of Kant's more tentative formulations of causality as a regulative principle. Additionally, Cassirer also stressed that causality should be disentangled from some of Kant's other conditions, centrally continuity and substance and attribute.

“transcendental psychology”: Kant “does seem to flit obscurely across the stage”, a stage on which all kinds of protagonists and antagonists of classical causality and determinism took it up against one another.[264]

Weizsäcker was concerned with the classical and explicitly more narrow sense of causality which was he held to be provided by Laplace as the absolute certain prediction of the future course of physical processes when the initial conditions are fully known: “*daß bei gegebenen Anfangsbedingungen strenge Vorausberechnung möglich sei*”.[265] Indeed, quantum mechanics showed that such a sense of causality could not be upheld in an absolute sense. The fundamental uncertainties that arise on atomic scales of length implied that predictions can only be made statistically for large ensembles of events. Nonetheless, Bohr had said that our direct experience of things is necessarily bound up with classical concepts.[266] Weizsäcker agreed and stated that our “experiences of nature” is necessarily causal in the classical sense and that we can therefore not so easily give up on the classical causality based on strict dynamical laws. Moreover, Weizsäcker maintained, the alternative—statistical causality—is not intuitable and can therefore not save our understanding of nature.[267] On these assumptions, the most sensible alternative is a classical causality with a milder status, only valid as a concept constitutive for a human and intuitive experience. Cassirer could not have assented to such a causality because it results a rupture within the objective structures of quantum phenomena, centrally between causality and the intuitive continuous succession in time.

---

[264] Nagel 1938.

[265] Weizsäcker 1937.

[266] See also: Schmitz-Rigal 2002 p. 316

[267] Weizsäcker did not say precisely why statistical causality was not intuitable. A good guess is that there appears to be no deeper cause for atomic events which happen only in accordance with a statistical law on large scale. The individual cases appear to be produced by chance. This problem will be discussed in the following chapter.

9 DETERMINISM AND INDETERMINISM

It is remarkable that of the physicist correspondents and reviewers only Weizsäcker noticed that in *Determinismus* Cassirer's exposé of causality was embedded in a much deeper thesis.[268] Cassirer claimed besides the aprioricity and generality of the principle causality that we must let go of the classical presupposition of the possibility of the "full and complete determination" of existence. (DI p. 236: p. 190) Weizsäcker stated that this thesis was widely established. The rejection of the principle of complete determination affirmed for Cassirer the tendency of science to develop from a substantial to a functional point of view.[269] Moreover, as Weizsäcker saw, the causal controversy was for Cassirer only an effect of this much more fundamental revelation. Even though Cassirer's solution may not have sufficiently taken into account the radical contradiction between classical causality and determinism and the view that individual processes are determined by "chance", I will sketch in this chapter how Cassirer's view nevertheless met an important part of the core of the physicists' critique.

As we saw, Exner had showed that claims of the universal status of strict universal dynamical laws were problematic. On this account, the laws of conservation of energy and momentum actually only deal with laws of averages and lose their validity in sufficiently minute ranges of time and space. Exner's stance conflicted with Planck's deep concerns with the human capabilities to understand nature. He contended that nature does not ask whether she reveals herself in an understandable way or not, not always having or displaying a "deeper" cause for phenomena.[270] His conclusion was that "chance" (*Zufall*) must be something that is objectively given in nature.[271] (DI p. 108: p. 86) This, Cassirer argued, was a bold claim, on the fringe of pure metaphysics. Yet, Cassirer wrote that Exner had realized that the fundamental problem consisted precisely in determining how far a "nature" is "given" to us at all, and what is meant by being "given". It was Exner's willingness to carry through what Kant had called the "Copernican revolution" that the question of the primacy of either statistical or dynamical laws completely lost its sense. This meant that physical research was confronted with a deep epistemological problem.

A cosmic indeterminism appeared to be radically affirmed when it turned out with the development of quantum mechanics that even at the microscopic or sub-microscopic level the state of a physical system could never be fully determined. With the statistical interpretation of the quantum mechanical wave function, Max Born insisted that a deterministic interpretation for which "a closed system is *entirely determined* by the state of the system at a certain time, can no longer be maintained."[272] Whereas Born and Heisenberg had centrally claimed the failure of causality, some also proposed that quantum mechanics represented a "triumph" for

[268] Weizsäcker 1937. The thesis was also noted by the philosophers Antoni (1938) and Nagel (1938).

[269] Four years later, Weizsäcker also centrally claimed this himself in two articles on the meaning of contemporary physics. See: Weizsäcker 1941a and 1941b.

[270] Stöltzner 1999 pp. 103-107.

[271] Exner considered indeterminism to be a tentative worldview. (Stöltzner 1999 p. 87)

[272] See: Born 1927 p. 241. See for instance: DI: p. 116.

indeterminism. For instance the astrophysicist and mathematician Arthur Eddington who said in 1935 that therefore physics was now "off the gold standard".[273] For Cassirer, in contrast, a full-blown indeterminism was for from a necessary conclusion. Moreover, it was even a looming danger.

The determinism of the Laplacean demon was brought down for good. Quantum mechanics denied the assumption that all fundamental physical relations allow for absolute certain predictions. As all commentators of *Determinismus* highlighted, this suggested to take into consideration a fundamental failure of determinism. In Cassirer's sense of determinism this failure could be phrased as: causality was not universal in the sense that not all events follow in accordance with a necessary rule. However, we already saw that Cassirer said that all laws of physics, whether dynamical or statistical, were necessary rules and universally presuppose causality: the statements of the theory represented an objective ordering according to law. (DI p. 108: p. 86) Even though Cassirer agreed that epistemology must take into account a "physical state" that is "not completely determined" (*durchgängig bestimmt*), (DI p. 236: p. 190) Cassirer also met doubts about determinism with a plea for the "determinateness" (*Bestimmtheit*) of empirical reality. This plea was based on the epistemological primacy of the determinateness of law.

Instead of treating statistical laws as a sign of indeterminism, a viewpoint toward which many physicists tended, Cassirer argued against this title because he believed that it gave rise to the "most dangerous equivocations", (DI p. 111: p. 89) both concerning the theory of knowledge and, as we will see below, the theory of freedom. Cassirer argued that chance, randomness, arbitrariness (*Willkürlichkeit*) and indeterminism provide the worst possible support in understanding scientific rationality. There actually is gold to be found in physics, Cassirer said, and the amount is sufficient to protect the indeterminism of quantum mechanics against speculative interpretations concerning man's general *Weltanschauung*. (DI: p. 119-122) Let me explain why Cassirer thought this was so. First, I will explore why his correspondents found that Cassirer's treatment of indeterminism was insufficient.

9.1 The core of the physicists' critique

Notwithstanding their veneration for Cassirer's deep historical knowledge and philosophical insights, Born, Laue, Weizsäcker, Frank and Pettersson were all somewhat dissatisfied with what Weizsäcker called Cassirer's "light" stance toward classical causality.[274] Their criticisms of Cassirer's attempt to rehabilitate causality were not easily waived. In general, the physicists' critique could be summarized by saying that Cassirer's approach excluded the ability to distinguish sufficiently between classical physics and the new quantum physics.

---

[273] Cassirer quoted at length Eddington's *New pathways in Science* (1935). (See: DI: 120) Eddington was famous for his expedition during a solar eclipse in 1919 to observe the bending of light emitted from the stars as a result of the sun's gravitational field. This famously affirmed the predictions of general relativity.

[274] Nagel (1938) and Antoni (1938) shared this dissatisfaction in their reviews. Weizsäcker was of the opinion that it was as if Cassirer was presenting a collection of uncontested and therefore trivial truths. He concluded patronizingly that the contemporary "aprioristic thinking philosophers" were not willing to meet the needs of the physicist. (Weizsäcker 1937)

As Frank formulated it in his review, the difficulty contained deeply within Cassirer's work was that *Determinismus* leaves us clueless as to why the new atomic physics is deterministic in a very different sense than classical mechanics. Frank considered an experiment in which we would fire a beam of electrons at a disc. Classically, he said, one can in principle hit the centre of a disc with any approximation. Quantum mechanically, however, the scattering effects of the beam are not reducible to a value below a certain limit, meaning that the theory forbids us to hit the centre of the disk with infinite precision.[275] This was a crucial breach with the classical concept of determinism. Unfortunately, Frank did not specifically address the problem of classical versus quantum mechanical determinism in the remainder of his review. Nonetheless, his suggestion was that *Determinismus* should have done so in order to provide a serious epistemological treatment of quantum mechanics. Similar comments will follow.

For all German scientists and scholars, international relations were becoming increasingly difficult to maintain under National Socialist rule. Letters would not always arrive or arrived with much delay. Such practicalities exerted a considerable constrain on Cassirer's attempts to promote *Determinismus*. Frank, for instance, noted in a letter to Cassirer that his copy of *Determinismus* had been delayed with the post. He also wrote that he organised reading sessions of *Determinismus* in a colloquium for *Wissenschaftslogik* and that when reviewed and discussed, he would inform Cassirer of their findings.[276] (ECN 18: 137. Frank *Ohne Datum*) Regrettably, chances are slim that the planned colloquium ever took place as Frank fled to the United States in 1938. Disregarding the fact that the comments in the letters of the physicists were few and often short, the responses Cassirer received contained some very provoking thoughts in addition to the critical reviews.

According to Born, the case of indeterminism was not as severe as it may have seemed.[277] (ECN 18: 19-3-1937) Born wrote Cassirer that if the matter of causality depended only on the lawfulness of experience as such and not on any "special mechanistic form", he would happily agree, even when one would call this lawfulness determinism.[278] However, Born added, the way Cassirer settled with the Laplacean demon was not sufficient to refute "the more narrow form of classical laws" and what people usually understand by determinism. Born suggested that classical determinism should be treated as a "logical problem" and it must, contrary to Cassirer's approach, be shown rigorously why it has been disproven by the new physics. Merely defending from a historical or epistemological perspective why Laplace's "metaphor", as Cassirer called it, didn't make much sense as a universal formulation of

[275] The "possibility of pre-determination" (*Möglichkeit der Vorherbestimmung*) should be described in terms of specific experiments. (Frank 1937 p. 74) In light of Cassirer's epistemology of function, however, we can say that Cassirer did not attempt to understand the possibility of determination and pre-determination in an operational sense but to understand them as synthetic ideas.

[276] Frank hoped to meet Cassirer personally on a congress in Paris, by which he presumably means either the "Ninth International Congress for Philosophy" (*Congress Descartes* in Paris (1937)) or the "Third International Congress for the Unity of Science" (Paris 29-31 July 1937). (See: ECN 18: footnote 374.) There is no evidence affirming that Cassirer visited these congresses.

[277] In his letter, Born referred to indeterminism as "*meinen Indeterminismus*". (ECN 18: 19-3-1937)

[278] This is very close to what Cassirer suggested.

causality and arguing that causality had in fact been a much broader notion was insufficient as a disproof of classical causality and determinism. It would not convince Einstein, Planck, Laue or other more classically minded physicists, Born said.

Born summarized the classical formulation of causality which was according to him still trusted upon by Planck and Einstein and had been combatted by himself as wrong: "dF^2 / dT^2 = *gegebene Funktion der Zustandsgröße F und ihrer räumlichen Ableitungen*."[279] (ECN 18: 19-3-1937) When applied to the whole world, Born said, this formulation is equivalent to the determinism of the Laplacean demon. In light of his remarks, we can further specify Born's interpretation of a Laplacean determinism as the equation of motion "$dr^2 / dt^2 = F(r)$" in which r represents the position of a body and $F(r)$ the vector sum of forces acting on the body. If we also assume that the equation always has a unique solution for a given initial position r_0 and velocity v_0, then the interpretation implies that if we know the positions and velocities of all particles of a system at a given instant and all the forces present, we can predict all the future and past states of the system.[280] This definition of determinism has proven to be incorrect, Born informed Cassirer.[281]

Quantum mechanics leaves unanswered questions about the course of development of "individual processes". Indeed, the demand of determinism as the demand of unique solutions to differential equations was clearly contradicted by the new atomic physics. Quantum mechanical states are not clearly defined with respect to all observables and the calculations of measurement outcomes do not provide unique solutions. We can therefore no longer hold on to what we have called "causal determinism", the claim that every occurrence results necessarily from antecedent events in accordance with the laws of nature so that we can produce perfect predictions.[282] "*Wenn Sie einmal mit Einstein diskutiert hätten, würden Sie diesen Punkt sehr ernst nehmen. Er ist noch immer der Kronzeuge aller derer, die glauben, daß die Physik demnächst wieder reumütig zu Newtonschen Prinzipien zurückkehren wird.*" (ECN 18: 19-3-1937) If only Cassirer would have discussed this with Einstein, Born wrote Cassirer, then he would probably have been forced to sharpen his ideas.

Indeed, taking into account more carefully the various positions with regard to the thesis of determinism might have increased the direct value of *Determinismus* for physicists. Also, it might have saved its readers some trouble when Cassirer would have underlined more

[279] It appears, comparing Born's statement with the definition of determinism that follows, that Born had written or meant to write dR^2 or dr^2 rather than dF^2.

[280] This definition of Laplacean determinism is provided in: Van Strien 2014 p. 25. Further evidence that Born had this definition in mind is found in his article of 1927: "*daß die Kenntnis des Zustandes (nämlich der Lagen und Geschwindichkeiten aller Materieteilchen) in einem Augenblick den Ablauf eines abgeschlossenen Systems für alle Zukunft determiniert*." (Born 1927 p. 239)

[281] Still, Born thought that the laws of quantum mechanics were "just as satisfying" as a basis for determinism. (ECN 18: 19-3-1937) Born probably had in mind the completely deterministic evolution of the Schrödinger equation, for which a similar equation could be set up, not in normal geometrical space but in quantum mechanical configuration space.

[282] Born said the following in 1927: "*Die Kenntnis der Funktion nun erlaubt, den Ablauf eines physikalischen Vorganges zu berechnen … nicht im Sinne kausaler Determiniertheit, sondern im Sinne der Warscheinlichkeit.*" (Born 1927 p. 241) (See footnote 177, 230 and 327)

clearly that he was not defending causality in a physical sense or as a "logical problem", i.e. as a "rigorous" claim about the solutions to equations or the possibilities of prediction, but as a universal point of departure of scientific reason.

9.1.1 Indeterminism

In his letter, Frank wrote that Cassirer's ideas stood very close to his own. Whenever he seemed to have been "critical" of Cassirer, this similarity must be taken into account to sooth any perceived intellectual hostility. What is special and remarkable about Cassirer's philosophy, Frank remarked, is that more than any other philosopher Cassirer moved the "logical constitution" to the foreground, revealing a deep methodological structure. When, however, Cassirer would have consistently carried out this move, his point of view would lead to a far reaching "arbitrariness" (*Willkürlichkeit*) within the logical constitution of science. (ECN 18: 137. Frank *Ohne Datum*)[283] Frank's review of *Determinismus*, which appeared later in 1938, did not discuss this possibility, even though it has been commonly acknowledged that Frank generally favoured indeterminism.[284] Unfortunately, none of the physicists dealt with the question in their reviews. The preserved correspondence, however, provides more insight.

Frank's concern was also voiced by Laue.[285] Laue wrote Cassirer that with respect to knowledge of large systems, physicists tackle the problem with more appropriately sized tools. When for instance considering the macro-phenomena covered by Laplace's demon, physicists dispose of the dynamical laws of Newtonian mechanics and turn to laws like Boltzmann's statistical laws, Laue said. Like Born had also said in his letter, statistical methods are usually employed to deal with our incomplete knowledge of the initial state. (ECN 18: 19-3-1937) This was wholly different in quantum mechanics. The physicist is typically not interested in the fate of the individual atom, Laue suggested. When not taking into account the fate of the individual atom, the classical notion of determinism as prefect prediction can be maintained also for statistical mechanics. (ECN 18: 23-3-1937) Nonetheless, Laue continued, very much in line with his Kantian concern for individual existences as discussed in part I, the statistical laws of quantum mechanics express a certain "indeterminateness" about the individual events that goes beyond the voluntary abandonment of dynamical laws seen in statistical mechanics.

This time—and all physicist commentators of *Determinismus* hinted at this—indeterminism was not a matter of heuristics but an apparent necessary result for the underlying logic of the theory itself. The formalism of Schrödinger's equation clearly was fully deterministic, yet the observable physical properties were not. Even if the present of a quantum mechanical wave function is fully known, observation is inherently unpredictable and

---

283 Frank's letter was send somewhere in the period March-June (1937), right after Cassirer had sent around copies of the just published *Determinismus*.

284 See generally: Stöltzner 2003.

285 Laue was a fierce opponent of National Socialism. He took a stance against the movement of *Deutsche Physik* which opposed for example Einstein's relativity theory as a form "Jewish physics". In 1935, he, Max Planck and Otto Hahn organized and attended a commemoration, forbidden by the national socialist government, on the anniversary of the chemist Fritz Haber's death who had emigrated because as a Jew he was removed from his job. All Laue's letters are written within the timespan of less than three weeks.

incompletely determined. As the equations that determine the outcomes of measurements typically have multiple solutions, so do the measurements of identical systems provide different results. We can therefore no longer speak of a nature that is fully pre-determined in and by itself and a kind of indeterminism seems to slip into physical theory itself.

Born and Heisenberg strongly emphasized that quantum mechanics shows that our knowledge of the individual events is *merely* statistically determined. As there turned out to be no way to predict individual atomic events, but only to produce statements that hold strictly, but for large ensembles of events only, the thesis of determinism had to be given up. Statements about individual events hold with a certainty that is typically less than unity. Moreover, it turned out that the minimal uncertainty in the simultaneous measurement of conjugate observables, centrally position and momentum, is directly proportional to Planck's constant *h*. If one property is precisely defined, the other is not. It is said that Born and Heisenberg therefore suggested the epistemological assumption of a "fundamental indeterminism" in which Planck's constant would represent the "universal gauge of indeterminism".[286]

As Heisenberg reflected much later in 1958, it seemed that the probability distribution given by the wave function represents *at most* a "tendency for events and our knowledge of events."[287] Pettersson formulated this apparent tendency wonderfully in his review of *Determinismus*:

> *It is somewhat difficult to understand why there should be a tendency of the 'collective' to be law-abiding, when the individuals are assumed to rebel, unless one ascribes to the individual a kind of volition to attempt to conform with the law, which is more or less successful according to the rules of trial and error.*[288]

Pettersson immediately added, however, that such views may perhaps be discarded as too metaphysical for it would assume the existence of something that lies outside the possibility of experience. As we will see, Cassirer's argument was very similar.

Mocking Cassirer in a humouristic and sympathetic way, Edgar Wind, an art historian and philosopher who had studied with Cassirer, informed him about a joke that explained the situation of modern physics very well: A biologists explains to someone that the mutations observed in genetics are too small to pose a thread for biological determinism. The interlocutor replies telling him that a housemaid once gave birth to an illegitimate child, but that she justified it to her superiors by saying that it was just a very small one. No matter how small the aberration, Wind suggested with this analogy, it should be crystal clear that an absolute determinism is infringed upon by the laws of quantum mechanics.[289] (ECN 18: 6-4-1937) Wind

---

[286] Jammer 1989 p. 371.

[287] Heisenberg 1958 p. 46.

[288] Pettersson 1937.

[289] Wind asked: "*Aber haben wir nicht durch Ernst Cassirer gelernt, daß die größten Revolutionen der Denkart sich im Infinitesimalen zugetragen haben*?" (ECN 18: 6-4-1937) Antoni found in a similar vein that Cassirer was blind for the radical philosophical consequences of quantum indeterminism. Indeterminism points toward an ineliminable objective reality outside the mere phenomena, Antoni argued. Against positivist, neo-Kantians and the new generation of physicists, the Hegelian Antoni

thus suggested that Cassirer's treatment did not sufficiently acknowledge this revolutionary discovery.

In light of Cassirer's neo-Kantian outlook, Frank's demand of taking up a notion of "arbitrariness" (*Willkürlichkeit*) within the logical constitution of scientific reason appeared to be an obvious request. (ECN 18: 137. Frank *Ohne Datum*) However, Cassirer was fundamentally unable to grant Frank's request. Adopting a genuine indeterminism was for Cassirer impossible centrally because it was the sign of a kind of agnosticism in which the "unknowable", i.e. an *ignorabimus*, becomes a presupposition of knowledge itself. (DI: p. 130, 149) As his principle of causality expressed, all scientific knowledge was according for Cassirer based on the assumption that there is a natural orderliness according to law that is intelligible. (DI: p. 60) But because Cassirer barely addressed the question directly in *Determinismus*, it often remained a mystery why exactly indeterminism was for Cassirer what Wind called an "illegitimate child". In what follows, I will further explore Cassirer's reasons.

9.2 Cassirer against indeterminism

Cassirer granted that on atomic scales of length, it made no sense anymore to speak of nature as being absolutely pre-determined or composed of completely determined entities. Cassirer granted that the new physics flatly contradicted this classical epistemology. In Kant's work, Cassirer explained vividly, "reality" and "complete determination" (*durchängige Bestimmtheit*) had been "interchangeable concepts". (DI p. 235: p. 189) "Every *thing*," Kant declared, "is subject to the principle of complete determination [*Grundsatz der durchgängigen Bestimmung*]."[290] This meant for Kant that "if *all the possible* predicates of *things* be taken with their contradictory opposites, then one of each pair of contradictory opposites must belong to it."[291] This was blatantly not the case with quantum mechanics.

The decay of individual radioactive isotopes, the scattering of photons upon collision with an electron and the jumps of electrons between different orbits around the core of the atom for example, could not be perfectly predicted as quantum mechanical states are not precisely defined with respect to all observables. Moreover, it was even impossible to define precisely both the position and velocity of individual entities, which was perhaps the most important precondition of the Newtonian-Laplacean determinism as the perfect prediction of matter in motion. Cassirer concluded that a change in the meaning of reality had taken place. As Weizsäcker quoted: "*Jetzt können wir die Existenz nicht mehr als ein vollständig und durchgängig Bestimmtes ansehen*".[292] (DI p. 236: p. 190) The classical assumption that all physical variables always have a precise value radically failed in quantum mechanics, which was expressed most pointedly by the physical principle of uncertainty. Cassirer was of the

---

reasoned that quantum indeterminism radically points out the necessity of taking into account the concept of being in a much stronger sense than merely a methodological presupposition. (Antoni 1938)

[290] Kant 1998 A571/B599. Kant also spoke here of the fundamental requirement of "determinability" (*Bestimmbarkeit*).

[291] Ibid.

[292] Weizsäcker quoted this sentence is his review (1937).

opinion that the apparent "crisis of causality" was only an effect of this much deeper issue.[293] Weizsäcker was the only physicist to explicitly take note of this relation.

As Weizsäcker suggested concerning Cassirer's view, and also later claimed himself in two articles in 1941, quantum mechanics affirmed radically that instead of the category of "cause and effect" the category "substance and attribute" or "thing and property" had become superfluous.[294] Physicists, on this view, could no longer base their epistemology on an ontology of the independent existence of some kind of physical entities or substances. Cassirer said that statements of physical entities make sense only under the conditions of physical cognition. (DI: p. 132) He said that this could generally be realized by looking at the principle of uncertainty, because the reality that we can ascribe to things and properties is only empirically definable under its condition and not under the classical expectation of an absolute determination. With the physical uncertainty between conjugate variables, centrally between the properties of position and momentum, the talk of a "dark nucleus" of existence independent of scientific knowledge—to which scepticism habitually refers when saying that we will never know reality—completely lost its meaning. (DI: p. 135)

Interpreting Laplace's analogy of the perfect prediction of things on the basis of our knowledge of their properties as the only possible definition of determinism would be a false self-gratification of reason, Cassirer said. Such a statement would immediately give way to the inherent tendency of thought toward a direct hypostasis or "reification" (*Objectivierung*) of scientific concepts, centrally mass, motion and force. Instead, Laplace's formulation was merely an "imaginary focus". (DI: p. 24) On Cassirer's account, disregarding the status of such an idea conflates substance and function. As such, a metaphysical determinism would surpass the fact that the concept of thing (*Dingbegriff*), given independently in itself, is not so much the starting point of physical knowledge but its *telos*. In this sense, Cassirer found in modern science a peculiar reversal of the classical epistemological relation between observation and law and the relations between thing and structure, in short, a reversal of substance and function. This development was also reflected in quantum mechanics, for the theory required that its "formalism is interpreted at its end".[295]

This should make clear why Cassirer was somewhat reticent to rigorously disproof Laplace's demon as a definite form of determinism. *Determinismus* unquestionably proceeded from a way more general and broader perspective than his physicist commentators appear to have demanded. As a result, reticence was sometimes mistaken for reluctance. Moreover, Cassirer had some serious objections against the demand of physicists to acknowledge the indeterminism of theory. Frank's request for incorporating a notion of *Willkürlichkeit* within the logical constitution of scientific reason could certainly not be granted. Let me further

---

[293] There was much talk of a crisis in science during the Weimar era. See Hans Hahn's lecture from 1920: 'Krise der Anschauung' (1933). See also the discussion about the "crisis of reality" between Riezler (1928) and Fleck (1929). Also well-known is Edmund Husserl's *Die Krisis der europäischen Wissenschaften und die transzendentale Phänomenologie* (1936). In *Determinismus*, Cassirer referred to the idea of crisis with respect to the decoupling of space and time from the a priori demand of causality. (DI: p. 164)

[294] See: Weizsäcker 1941a and 1941b.

[295] This is Max Jammer's expression. See: Jammer 1989 p. 343.

explain in the remainder of this chapter how Cassirer's objections stemmed from deep within his functional theory of knowledge.

9.2.1 Thingness and lawfulness

As Cassirer centrally claimed throughout his career, the pioneers of the mechanistic world view Kepler, Galileo, Descartes and Leibniz started their intellectual endeavours from the Platonic ideal of the identity of mathematics and nature. (DI: p. 12-13) Also Heisenberg is said to have believed in this identity.[296] Antoni wrote in his review that Cassirer widened his own perspective by letting go of this metaphysical view. Since Hume and the problem of induction it had been clear in philosophy that the possibility of what Antoni described as a "mathematical determinism" was excluded.[297] To believe that our concepts were at once mathematical and metaphysical was an inadmissible hypostatis of the ideal of reason, Cassirer said. (DI: p. 24) Leibniz had for instance understood determinism as "metaphysical mathematicism", Cassirer said. (DI: p. 12) But, thought had moved on with Kant to a more critical determinism based on causality and also space and time as a priori conditions of experience and knowledge. The classical demand of complete determination, that for every property there is a precise number, could now be loosened.

With the breakdown of this residual metaphysics of causality in physics, Antoni remarked, this science once again showed to be "a bit late but always on time" with respect to critical philosophy.[298] Even though Antoni's phrasing was somewhat polemical, it is clear that Cassirer attempted to decentralize the tendency of thought toward an unconditional reification of its mathematical schemes and to make way for a mediated and limited reification or the "objectifiability of nature".[299] Immediate reification of our intuitions, independent of the conditions of experience, is the greatest and most difficult to avoid danger, always looming within the deepest caverns of knowledge. Instead, Cassirer said, the process of hypostasis must be restricted to the critical foundations of knowledge, for "the restriction of the understanding to the conditions and limits of possible experience is … the same as its sole realization". (DI p. 31: p. 23) This was in accordance with the "transcendental insight" that like the absolute ideal, also objective reality or "thingness" (*Gegenständlickhkeit*) is not so much "given" but "set as a

[296] Jammer 1989 p. 362.

[297] Antoni 1938

[298] "…*un po' tardi ma sempre in tempo*". (Antoni 1938)

[299] Weizsäcker centred his attention on an apparent loss of the objectifiability of the classical intuitions of space-time and causality, not only in his review of *Determinismus* but also in two articles published in 1941. See: Weizsäcker 1937; Weizsäcker 1941a pp. 193-194; and Weizsäcker 1941b pp. 490, 493, 497-498. For Cassirer, however, quantum physics did not imply a failure objectifiability but only of a "naïve" objectifiability. The task of reification was seen by him as one of the most primal conditions of objectivity as such. Cassirer spoke of the fulfilment of the task of reason to proceed toward the hypostatis of its concepts in an "absolute completeness" of experience as their highest justification. (DI: p. 18-19) This relates to the task-like character of reality discussed above. (See footnotes 42, 89, 302 and 372)

task" (*aufgegeben*).[300] "[I]nstead of complaining that we cannot penetrate to the 'inside of nature', we have to realize that for us there is no other 'inside' than that which is revealed through observation and analysis of phenomena."[301] (DI: p. 135)

The relations between "things" and "properties" had to make way for a more functional understanding in which we can only speak of a thing in as far as it is given under the laws of nature and the regulative and constitutive conditions of knowledge. As Frank put it in his review: "*nun* [*steht*] *nicht der Dingbegriff, sondern der Gesetzesbegriff im Vordergrund*".[302] Indeed, the concept of law (*Gesetzbegriff*) must, according to Cassirer, be regarded as epistemologically prior to the concept of object (*Objektbegriff*).[303] (DI: 131) In Frank's opinion it was both right and very apt of Cassirer to claim that the general epistemological replacement of thingness by lawfulness is affirmed by the insight that we can no longer understand the physical state as something that is fully and completely determined (*vollständig und durchgängig bestimmt*). (DI p. 236: p. 190) It implied, as Frank saw, that we can only speak of a "physical being" under the conditions of physical knowledge and not *vice versa*. The reality of the physical object, is constructed only through and by the physical relations of for instance of uncertainty that positively enable us to form representations. In other words, laws provide the structure on the basis of which observations can be made.

With regards to Cassirer's focus on lawfulness (*Gesetzlichkeit*), it is worthwhile to shortly consider the concept of *Zuordnung* (coordination).[304] In his letter to Schlick, Cassirer had additionally suggested that what is a priori in the strictest sense could possibly be captured by what was called the "*Eindeutigkeit der Zuordnung*". As the most general characterization of the synthetic a priori, this concept was identical with the principle of the "unity of nature", Cassirer wrote.[305] (ECN 18: 23-10-1920) *Zuordnung* is probably best translated as "coordination" and represents what could be called a "semiotic" relation between signs or concepts. To coordinate signs—or the concepts they represent—means to establish a relation of determinations between them. The role of coordination is well illustrated by Cassirer's view on the mathematical principle of the formation of series, which Cassirer took to express the essence of mathematics.[306] (SF p. 124) Explained roughly, series are formed on the basis of a certain rule which is defined over specific sets of elements, usually numbers. In such a relation, the meaning of the numbers is fully dependent on the rule that determines all the numbers in

---

[300] The task of reification occupied a central place in Cassirer's work. See for example: DI p. 16-17: p. 18-19, 24. Felix Kaufmann notes this and speaks of "*Verdinglichung*" and "*Vergegenständlichung*". (Felix Kaufmann 1949 p. 130) (See footnotes 42, 89, 301, and 372)

[301] See also: DI: p. 179.

[302] Frank 1938 p. 74.

[303] Weizsäcker spoke of a "relativization" of the concept of thing. (Weizsäcker 1937)

[304] There is no direct translation of the nuon *Zuordnung* or the verb *zuordnen*. Like most translations, we will stick to "coordination" and "to coordinate". Other natural translations are "to map", which is too similar to "to correspondent"; "to correlate", which emphasizes the activity; and "to assign", which captures that it is a relation between concepts represented by signs.

[305] Cassirer discussed Schlick's concept of *Zuordnung* in: Cassirer 1927 (ECW 17) e.g. pp. 54, 66. See on this topic: Ryckman 1991 and Neuber 2011.

[306] See: Neuber 2011 p. 142. Also: Ihmig 2001 p. 205.

the series of transformations of which the specific element is a part.[307] *Zuordnung* designated precisely such a relation.

Schlick and Cassirer had a very similar opinion on the topic. What is of importance for us is that Cassirer focussed on the "law of coordination" (*Gesetz der Zuordnung*). According to this law, or rule, we have coordination when chains of representations, or signs, mutually correspond in a functional sense, meaning that all the respective connections are established in a clear and unambiguous, or unique sense. This univocality (*Eindeutigkeit*) of coordination was connected to the principle of the unity of nature for Cassirer in multiple ways. First of all, unity, or the univocality of coordination, is for Cassirer not found with any particular content but rather in the form of an objective "system of valid relations". (ET p. 415) It is in this sense that Cassirer suggested the following analogy: "*Das Urteil bildet das Wesen des Beurteilten so wenig ab wie die Note den Ton, oder wie der Namen eines Menschen seine Persönlichkeit*."[308] The "essence of judgement" is not contained in any specific judgement but is rather presupposed in the whole. Like the unity of nature, the principle of the univocality of coordination must therefore be seen purely as a regulative principle. Secondly, we find the presupposition that there is *one* nature about which we can establish truth following unambiguous and fixed coordinations. For Cassirer, in contrast with Schlick, the mutuality of coordination between theory and phenomena was only a regulative ideal.[309] Finally, there is the requirement that our mathematical operations always produce the same results. This was expressed in Cassirer's letter as the law-abiding character of experience in general.

Take for example the determinate numbers "π" and "e". Their existence of can neither be spoken of in the sense of physical existence, nor in the sense of psychological existence. The series and transformations that we establish by use of their definitions only say that one position in the ideal system of numbers is objectively necessary and determined definitively. (SF p. 124) Likewise, the existence of physical objects is for Cassirer completely determined by the coordination of physical quantities, which is determined in turn by definite—instead of indefinite—laws of nature.[310] Truth is not established in some unmediated or intuitive sense, by "seeing", on the one hand, the theory and "reality", on the other hand. Rather, the object is established strictly in a mediated sense, satisfying conceptual demands. It is only indirectly established by relations between "signs" (*Zeichen*) and Cassirer therefore said that we are dealing with "certain series of presentations". However, these structures "can never themselves be directly presented.[311] (SF p. 123) Cassirer wrote in 1910 that we must radically let go of the

---

[307] Think for instance of the infinite series of "Zeno's dichotomy" ($^1/_2 + {}^1/_4 + {}^1/_8 \ldots$) which is represented by the relation $\Sigma\ ½^n + ½^{n+1} + ½^{n+2} + \ldots$

[308] Cassirer 1927 (ECW 17) p. 54.

[309] See: Neuber 2011 p. 142. Neuber highlights that in contrast with Cassirer, Schlick interpreted *Zuordnung* realistically as a relation between on the one hand conceptual structures and on the other hand a non-conceptual reality. (See for Cassirer's view on Schlick's demand that coordination (*Zuordnung*) is between "sign and "signified" (*zwischen Zeichen und Bezeichnetem*): Cassirer 1927 (ECW 17) p. 54.) Nonethless, both Cassirer and Schlick held that in theoretical thinking "there is basically no relation other than that of correlation [*Zuordnung*]". (Schlick 1918 p. 383)

[310] Ihmig 2001 pp. 211, 219.

[311] (See footnote 12)

assumption that signs are direct signs *of* "some*thing* objective" or that they represent external predetermined objects, if you will. Rather than depicting some kind of objective reality, we are dealing with signs and concepts as *functions* of objectivity. (SF p. 304-305)

Now, the central newness of quantum mechanics was the inability to simultaneously assign unique and precise values to all measurable properties of a physical system. Yet, this was no threat to the demand of univocal and necessary relations because the laws of the theory universally apply and always provide us with the same results. Moreover, the fundamental uncertainty inherent in the simultaneous establishment of conjugate observables is always the same. Hugo Bergmann, a philosopher born in Prague who had immigrated to Palestine in 1920 and had also written on quantum mechanics, asked Cassirer whether the univocality of relations between cause and effect was not violated by quantum mechanics because in different cases we acquire different results.[312] Although Cassirer's reply has been lost, we can say conclude that his answer must have been in the negative.

I will consider the case in which we say that the laws themselves are nevertheless indeterminate in the following section. Instead the conclusion of an indeterministic theory or indeterministic physical reality, we find in *Determinismus* the suggestion that physics dealt with a transformation in the notion of physical state. As Nagel put it, "the relations asserted by physics must hold between *different physical states* than the states contemplated by classical physics."[313] The seemingly natural conclusion that reality had turned out to be fundamentally indeterministic is not to be proven or disproven on the basis of the theory itself, because the principles and laws of the theory define the very meaning of physical reality. Herewith, Cassirer remarked, "we appear to jump from the frying pan into the fire."[314] (DI p. 159: 128) Instead of opting for a fundamental indeterminism of nature, Cassirer emphasized that these "not completely determinate physical states"[315] were grounded in a determinate objective structure of necessary relations. Seeing that the physical state is strictly defined by the determinate expressions of the theory, or, put differently, that the physical state is solely constructed through the intersection of unambiguous laws, resolved for Cassirer the problem of indeterminism. Let me further explain this determinacy of law.

---

[312] See: Bergmann's *Der Kampf um das Kausalgesetz in der jüngsten Physik* (1929). Bergmann wrote Cassirer on 9-12-1937. His letter is accessible online at: http://agora.sub.uni-hamburg.de/subcass/digbib/ssearch (visited on 26-11-2014).

[313] Nagel 1938.

[314] The original German expression is: "*Und hier scheinen wir von der Scylla in die Charybdis zu geraten*."

[315] Even though this term is not Cassirer's, it makes much sense in light of Cassirer's rejection of indeterminism. Speaking of "indeterminate states", which is logically speaking a viable alternative, would emphasize exactly that what Cassirer was opposed to, namely indeterminism as a general *Weltanschauung*.

9.2.2 Indeterministic theory?

John Michael Krois believes that since Cassirer acknowledged that we cannot any longer understand physical reality as being fully and completely determined, his principle of causality permitted both deterministic and indeterministic theories.[316] (DI p. 236: p. 190) To a certain extent, Krois is absolutely right. But, it should be noted that on Cassirer's view causality was a universal and therefore necessary principle, as the principle holds for all cognitive contents. Moreover, as Krois recognizes, causality made it possible for Cassirer that physical being can be cognized in the first place: "The type of determination prescribes limits to the being which we can attribute to natural things, and not the reverse." (DI: p. 194) Determinism thus holds in the sense that causality is a universal precondition for the type of being we can ascribe to the natural things captured by our "modes of determination" (*Modi der Bestimmung*). (DI p. 111: p. 89) "It is not being, determined by itself, that sets permanent limits to knowledge, with the absolute intrinsic nature of being remaining impenetrable." (Ibid.) Instead, nature is always "for us" and thus always appears as determined, not by itself, but by the structure of natural law and the absolute condition of lawfulness.

Kant had already emphasized that thought is quickly mislead by the metaphysical urge of the intellect for what could be called a pre-existing realm of the unconditional.[317] This urge often leads to the assumption of what could be called an "extra-theoretical substance" or an "undetermined remainder" outside the theory. Exner had already concluded that "chance" (*Zufall*) must be something that is given objectively in nature, independently of our knowledge. (DI p. 108: p. 86) The regularities we observe, Exner tentatively defended, were averages, exclusively produced by chance. Dynamical laws were reduced by Exner to "the ideal limit cases to which the real statistical laws converge."[318] On such a view, we could say that the most basic law is the "law of large numbers", as this law guarantees that the averages of a large number of experiments converges to the calculated expected value. In a way, it "stabilizes" the dynamical laws and thereby governs all happenings in nature. Herewith, Exner introduced what could be called "indeterministic laws".[319] Cassirer found that Exner's indeterministic laws were a movement into the right direction, for they showed that thought can establish strict laws based upon probability without losing coherence. However, Exner's indeterministic laws were not a sign of the true arbitrariness (*Willkürlichkeit*) or indeterminism of nature, Cassirer argued.

According to Planck, adopting a notion of indeterminism presupposes that the attempt to determine simultaneously the coordinates and the momentum of a particle is physically meaningful. However, the uncertainty principle suggested that it is not.[320] Its discovery does only compel to give up the aspiration to simultaneously establish a value for two non-commuting observables.[321] A failure of determinism demanded much more. Moreover, the

[316] Krois 1987 p. 114.

[317] Also discussed in: Schmitz-Rigal 2002 p. 358.

[318] Stöltzner 1999 pp. 104, 108.

[319] Ibid.

[320] Mills 2014 p. 37.

[321] Cassirer's plea for causality—and for that reason also for retaining some sense of determinism as the "determinateness of law"—was not strengthened by the hope for some deeper reality in which physical states are entirely and completely determinate with respect to each observable. Cassirer held that

mathematical methods of computation of quantum mechanics are perfectly deterministic. This was particularly so for the quantum mechanical wave functions. Schrödinger's equation fully fixed the evolution in time of the quantum mechanical psi-waves which allow for the statistical prediction of the results of measurement. Physical reality is defined as a conformity to these definite rules, not as a "non-conformity".

It is often said that if true randomness would be present, than we would be no way of modelling the outcome of measurements using probability functions. In a similar vein, Cassirer remarked that a genuine indeterminism, one that truly deserved the name, could only arise when the attack is aimed at the "determinateness of laws" (*Bestimmtheit der Gesetze*) as such. It can only be achieved when instead of attacking the "determinateness of individual events" we put at risk the lawfulness through which we perceive these individual events as being controlled (*dies Einzelgeschehen beherrscht denken*). (DI p. 147: p. 119) Modelling nature would then be an impossibility, for a model could get no grip on the phenomena. In a situation in which, for instance, the "law of large numbers" would not apply—when the averages would not converge to a single value—it would be impossible to establish a statistical law that prescribes the behaviour of the system. Reality would be too impermanent and unreliable to establish lawfulness at all:

> *'Nature's game of dice' then assumes a different form; it would no longer be concerned with a decision about the path of an individual electron; rather it would have to deal with the question whether nature, in a given moment, could apply this or that law, whether it can change its laws from case to case in a manner uncontrollable by our knowledge.*[322] (DI p. 147: p. 119)

Quantum mechanics protects itself against indeterminism in this sense simply because the theory does not attack the "determinateness of laws" as such. Laue agreed with this line of reasoning, but, he critically asked: does the determinateness of laws really protect quantum mechanics from the "indeterminateness" of the individual event? (ECN 18: 26-3-1937) No it did not. But, this did not imply for Cassirer that the theory itself was indeterministic. We were not faced with a dilemma between a reliance on the determinateness of laws and the *in*determinateness of individual events. Some sense of "nature as deterministic" must be withheld for the fact that individual phenomena are not completely determined with respect to each observable is a consequence only of determinate and fixed relationships.

As Antoni explained it, to satisfy a determinism in this sense, it is sufficient that physicists have succeeded in establishing laws of nature relying on unchanging and eternal

---

quantum mechanics was fully causal because it was based on unambiguous, univocal and strict laws. Whether the individual processes or entities were determinate or not would not have changed the matter for him. A so called "incompleteness" of quantum mechanics would therefore not have helped Cassirer. This is the most likely the reason why the EPR controversy was not addressed directly in *Determinismus*. It also could explain that Einstein's letter to Cassirer on this topic did not resonate with Cassirer's concerns. (ECN 18: 16-3-1937) (See footnotes 218 and 187)

[322] See on the Bohr-Einstein debate Don Howard's article 'Revisiting the Einstein-Bohr Dialogue' (2005: p. 12).

physical constants.[323] Cassirer already emphasized this in 1921 with respect to relativity theory as the "existence of 'universal constants' and universal laws which retain the same values for all systems of measurement." (ET p. 416) Moreover, all the fundamental quantum mechanical laws based on these constants, centrally Schrödinger's wave mechanics and Heisenberg's matrix mechanics, are universal and necessary. Instead of the classical substantialist reliance on the pre-given and pre-determined existence of individual entities as the fundamental determinants of the laws of nature, modern physics showed for Cassirer that existence is strictly determined by the objective relational-structures of the theories.

As also Nagel forwarded it, the "principle of indeterminacy" does not require the rejection of "strict laws of nature".[324] On the contrary, the principle simply indicated for Cassirer how strict objective laws can be obtained on the basis of a loyalty to experience. Cassirer said that we are dealing with a "condensation into law", apart from which no other objective reality exists. (DI: p. 132) As Born had stated, the physical processes that quantum mechanics describes are "statistically determined".[325] Similarly, Cassirer spoke of a "quantum mechanical determinism" also with respect to the uncertainty relations:

> *It is obvious that the uncertainty relations cannot and do not aim to transgress this frame of 'quantum theoretical determinism', for their actual meaning and content can only be understood where the firm structure of quantum theory is presupposed as given and universally valid. So little do the uncertainty relations waive the assumption of strict laws of nature that they actually give directions as to how to arrive at, and how to formulate, these laws in order to make them conform to the conditions of our empirical knowledge.* (DI: p. 122)

Therefore, asking whether individual atomic events have a cause or reason—a question that was answered in the negative by those who adopted an indeterministic view—would be senseless from the viewpoint of Cassirer's epistemology. The barriers of thought delimit the domain in which alone knowledge finds its significance. The conclusion of a fundamental indeterminism radically transgresses this fundamental requirement, Cassirer argued. To avoid dogmatically plunging into darkness and be "driven to consequences that submit to no touchstone of experience", the problem must be grasped discursively instead intuitively and by a finite instead of infinite intellect. (DI p. 31: p. 23) As a result, we must conclude that nature universally conforms to the formal lawfulness of quantum mechanics, for it provides necessary rules for calculating all possible measurement outcomes and a probability distribution which is uniquely determined by the description of the system.

---

[323] Antoni 1938. Antoni suggested that also the "uncontrollable perturbations" of physical phenomena that Bohr and Heisenberg spoke of—the necessary exchange of an uncontrollable amount of energy determined by the elementary quantum of action h as a result of our methods of observation—should be conceived as the result of a "determining cause". All the relations remain to be strictly lawful and thus causal. There is in this sense no reason to refrain to the "*negative* concept" of indeterminism and raise it to a general principle of cognition, Antoni explained.

[324] Nagel 1938.

[325] Born 1927 p. 241. (See footnotes 230 and 284)

9.2.3 The determinability of nature

More fundamentally, something like Exner's inderministic law was on Cassirer's neo-Kantian view also inconceivable because it contradicted the necessary tendency of the intellect to progress toward an increase in positive determinate content. The regulative principle of causality—the presupposition of order according to law as a condition for the possibility of scientific reason—expressed precisely this fundamental property of reason. Cassirer pointed out that even within quantum mechanics science centrally relies on the possibility of "determination". The new physics can, so to say, save itself from the "hybrid demand" that knowledge is only possible under the condition of the pre-determination of empirical reality, by replacing such a condition by the entirely sufficient demand of the "determinability" (*bestimmbarkeit*) of nature.[326] The establishment of strict function-dependencies is always based upon the presupposition of the determinability of phenomena.

As quantum mechanics showed, statistical laws are not necessarily of a lesser standing than dynamical laws. Both modes can achieve objectivity and rely on the logical determination and definiteness of concepts and principles. (DI: p. 119) Both statistical and dynamical determinations "produce certain limitations and fix certain permanent elements and connections within the uniform flow of experience" and thus allow us to know objectively.[327] (SF pp. 303-304) (DI: p. 137) No single method can be taken as a revelation of the "true" cosmic order of nature. As already discussed above, strict statistical laws implied for Cassirer a statistical causality. Moreover, Cassirer also argued that statistics and dynamics represented two "complementary" modes of determination rather than two opposites of determined and undetermined phenomena:

> *Dynamical and statistical laws were not regarded as two complementary methods and directions* [Weisen und Richtungen]*, as two different modes of description* [zwei Modi der Bestimmung gegenüber]*; they were instead opposed as the 'determined'* [Bestimmte] *and 'undetermined'* [Unbestimmte].[328] (DI p. 111: p. 89)

The "determinateness" of experience was now secured by a general process of determination. This general process of determination is in turn guided by the strive for a coherent unity of principles, laws and observations that regulates empirical and mathematical theorizing and is the ultimate criterion of objectivity.[329] In a critical sense, we can only confirm that the whole of these methods universally unfolds physical reality and progresses continuously and according to definite rules:

---

[326] Schmitz-Rigal 2002 p. 349. Moreover, see Kant on *Bestimmbarkeit*: Kant 1998 A571/B599.

[327] Cassirer quoted *Substance and Function*.

[328] Also Laue recognized that according to Cassirer statistical laws and dynamical laws are both the result of one process of determination (*Bestimmung*). (ECN 18: 23-3-1937) The use of the term "complementary" is added in the English translation. Cassirer did not use the term in the original German formulation. His statement should not be read in Bohr's sense as two mutually exclusive yet necessary perspectives. See below for a short treatment of complementarity in *Determinismus*.

[329] See for instance: SF p. 187. See the section on objectivity in chapter 7.

> [*T*]*he instrumental character of scientific concepts and judgments is not here contested. But the instrument, that leads, to the unity and thus to the truth of thought, must be in itself fixed and secure. If it did not possess a certain* [bestimmte] *stability ... it would break at the first attempt and be resolved into nothing. We need, not the objectivity of absolute things, but rather the objective determinateness* [Bestimmtheit] *of the method of experience* [des Weges der Erfahrung selbst].[330] (SF p. 322)

Cassirer reasoned that physical determinism must therefore be understood strictly in a relative sense, that is, as the highest possible degree of precision under the conditions of empirical knowledge. Heisenberg's principle of a maximal precision in the definition of the observables of position and momentum was precisely such a further empirical refinement of the causality condition. "Determination is thus re-established", Cassirer said, "but it is only valid for measurements which, according to the principle of quantum theory, are not capable of any increase in precision." (DI: p. 128)

What was apparently a negative situation, a mere human limitation in the attainment of knowledge of nature due to the uncertainty inherent in the observation of physical properties, turned out to be an eminently positive one. Cassirer wrote that "the abandonment of *absolute* determination restores the highest degree of *relative* determination of which physical knowledge is possible." (DI: p. 191) Therefore, Cassirer positively concluded that upon closer scrutiny the uncertainty relations proved to be a "helpful medicine" for causality. (DI: p. 128) As Antoni remarked, the concept of indeterminism was essentially negative and starkly contrasted Cassirer's positive concept of causality as lawfulness or conformity to law.[331]

As Antoni also recognized, the reason for this move was that Cassirer attributed a central significance to the productive synthesis of thought and the positive progression of thought toward the projective unity of experience.[332] Cassirer's analysis was aimed to show how the process in which something is "determined" (*bestimmt*) in and by cognition is fundamentally a productive synthesis. Its regulative foundation of knowledge could not be derived from other concepts nor be proven on the basis of experience itself. Causality as the "law-abiding character of experience in general" was therefore the "true a priori" of science as it proved to be the central fulfilment of the requirement that the fundamental principles of knowledge must be synthetic determinations. (ECN 18: 23-10-1920) Thus, Cassirer's arguments against indeterminism were not empirical, nor were they scientific in a positivistic sense.[333] Instead of discussing determinism as such a thesis, Cassirer based himself on considerations of a universal theoretical reason (*Theoretische Vernunft*) which engages in scientific theorizing. At times, this conflicted with what physicists seem to have expected.

In sum, Cassirer clearly took into account the "indeterminateness of observation" that physicists spoke of as he argued for a rejection of the classical and Kantian demand that all

---

[330] German edition: SF p. 428.

[331] Antoni 1938.

[332] Antoni 1938.

[333] As already discussed in chapter 6, this was also remarked in a negative sense explicitly by Frank. Frank 1938 p. 79.

observables always have precise values. Nonetheless, Cassirer's treatment of causality did according to all commentators not rigorously take into account the revolutionary discovery of quantum mechanics that individual microscopic processes are not strictly determined by what could be called "individual causes". As they rather appeared to be determined by chance or probability, indeterminism was radically affirmed, not in Cassirer's sense but as the non-uniqueness of the predicted outcomes of single measurements. Yet, if Cassirer would have made sure that the reader clearly recognized his stance toward indeterminism as a consequence of the central thesis of his book—that reason always bases itself upon the assumption of conformity to law and not on a "non-conformity" to law—it might have been better understood why Cassirer thought that a *Willkürlichkeit* could not be taken up within the "logical constitution of science" and that indeterminism contradicted the universal characteristics of scientific reason.

10 COMPLEMENTARITY AND THE PHYSICAL SYSTEM

It is an ongoing discussing whether Cassirer's philosophy of science can be interpreted realistically.[334] However "the real" is to be interpreted in such interpretations, it is clear, I believe, that Cassirer's standpoint is that of transcendental idealism: Reality can only be only be interpreted in the sense of a Kantian empirical realism, that is, as a pure imaginary focus of reason. In Cassirer we see a central role for the presupposition of existence in the sense of a reification of the law-like structures expressed by the functional-relational wholes of the theory. Recall in this light that concerning the question of the existence of individual entities or substances, Cassirer held that the concept of thing (*Dingbegriff*) was not the starting point but the *telos* of philosophical analysis. Cassirer concluded therefore that ultimately:

> *All these conceptual transformations in quantum mechanics become entirely clear only when it is constantly remembered that its conceptual terminology is an instrument which was not created for the description of 'things' and states but refers to the representation of the behavior of physical systems. We may continue to talk about 'things' in the sense of classical mechanics and of macroscopic experience, but we must take great care lest these things become rigid.* (DI: p. 192)

Also, there are in this respect some interesting parallels with Bohr's complementarity and his general view on quantum mechanics. In the preface to the English translation of *Determinismus* (1956) Henry Margenau argued that if Cassirer had been alive he would not have changed his ideas in light of the later developments of the Copenhagen interpretation. (DI: p. xx) Yet, Cassirer's concerns with the "objective" in a functional sense come across as wholly different from Bohr's and Heisenberg's somewhat negative conclusions about ascribing unambiguously an independent reality to the physical object. I will end with a condensed exploration of these themes. Further research is needed for more definite conclusions. Yet, the main drift of Cassirer's position should become clear here.[335]

10.1 Complementarity

Bohr's "principle of complementarity" was one of the most central ideas in the Copenhagen interpretation. The principle addressed precisely the conflict between Kant's transcendental aesthetics and Kant's concept of rationality which was also of great concern to the Marburg School and Cassirer. In matrix mechanics, a quantum system is typically in a superposition of multiple single "eigenstates" of an operator that represents an observable property like position, momentum or energy. Every eigenstate assigns one "eigenvalue" to the operator. Because in actual measurements of quantum systems we can always only obtain one value for an

---

[334] (See footnote 12)

[335] Consulted literature consulted on these topics: Bohr, 1926, 1927, 1929, 1935, 1937, 1948; Heisenberg 1958; Holton 1970; Jammer 1989; Pringe 2007, 2014; Schmitz-Rigal 2002; Sundaram 1972; Weizsäcker 1941a, 1941b. See also the bibliography below.

observable, Heisenberg and Neumann therefore proposed the assumption that in measurement the wave function collapses from a superposition of eigenstates with a spectrum of eigenvalues to one eigenstate with one eigenvalue. For Bohr, this showed a complementarity between our classical intuitions of space and time, which are necessary for the "possibility of observation", and the concept of causality, which is necessary for the "possibility of definition". Both views are equally necessary but mutually exclude each other because obtaining information in terms of clear events in space and time irreversibly destroys the possibility of unambiguously defining a physical system in terms of an undisturbed and closed causal evolution in time.[336]

Conventionally, Cassirer explained, this would lead to a contradiction in terms for we can no longer schematize causality within the perception of "pure time". Indeed, Cassirer wrote, "we can no longer combine causality with space-time description, let alone amalgamate the two in the manner of classical physics". (DI: p. 164) Addressed in Kantian terms, the conflict comes down to the incompatibility between the faculties of sensibility (*Sinnlichkeit*) and understanding (*Begriff*), the conflict Cohen, Natorp and Cassirer were already very concerned with. Cassirer considered Bohr's complementarity with much approval and explained that our understanding of space-time descriptions and causal descriptions indeed symbolize the "idealization of the possibilities of observation and of definition respectively."[337] (DI: pp. 115, 212) For Cassirer, quantum mechanics affirmed we can no longer affirm the Kantian demand that the manifold of the senses is necessarily unifiable by the understanding in a single, coherent, spatiotemporal experience.

Even though the assumption of a collapse of the wave function was not involved in Cassirer's argument, his exposition sounds remarkably similar to Bohr's complementarity. However, as we saw, for Cassirer the decoupling of the intuition of time and the concept of causality was essentially a result of the failure of the principle of continuity because in contrast with classical physics, quantum mechanical alterations can be engendered suddenly. Moreover, whereas Bohr's complementarity *merely* arose from the demand that our understanding of nature is based on ordinary language and common logic, Cassirer found in the sense of a "structural objectivity" that mathematical knowledge had to be freed from the demands of intuitive interpretation. Additionally, without stating the connection explicitly, *Determinismus*' concluding chapter presented the quantum physical wave-particle dualism as a natural consequence of the general non-uniqueness of perspectives inherent in every kind of

---

[336] This leads to what Weizsäcker called "circular complementarity", the complementarity roughly between the deterministic formalism and the process of observation. See: Jammer 1989 p. 369. Opposed to a mere "parallel complementarity" of the conjugate observables of position and momentum and time and energy, Bohr emphasized vividly that Schrödinger's deterministic formalism cannot be immediately connected to our ordinary sense perception because the wave equations are connected to a "Hilbert space" of which the number of dimensions is generally greater than the number of dimensions of ordinary space. See: Bohr 1927 p. 77. Yet, on a more instrumentalist tone, Bohr also stressed that the causal mode of description should be strictly linked to the laws of conservation of energy and momentum. See sections I and II in Bohr 1927. Solving this issue is by no means straightforward. However, for a comparison with Cassirer's interpretation it is best to stick to circular complementarity for it expresses the Kantian conflict between concepts and intuitions.

[337] Cassirer rephrased a line from Bohr's Como lecture: Bohr 1927 p. 54-55, 73.

knowledge—an idea to which large parts of Cassirer's *Philosophy of Symbolic Forms* (1923-1929) were devoted and typically a characteristic of what Cassirer had called the "significance function" of thought.

Laue wrote in one of letters that if we accept complementarity as a necessary condition of knowledge it would as a more fundamental principle incorporate both space-time and causality. (ECN 18: 26-3-1937) (ECN 18: 4-4-1937) Cassirer could not approve of this suggestion and disagreed with the proliferation that complementarity saw in fields like psychology, sociology and biology. It was inappropriate to extend the notion of complementarity to areas outside of its specific quantum mechanical context because it only presented physics with negative dialectics. The principle does not itself give direction to the scientific enterprise or our intellectual endeavours in general because for Cassirer, as we saw, knowledge needs first of all a positive determination.

10.2 The physical system

Bohr emphasized that as a result of complementarity it becomes impossible to discriminate sharply the behaviour of the system itself and the effect of the measuring device. Bohr said that the physical object is not well defined, because the human intellect can ascribe only either kinematic or dynamic properties to the object. We cannot establish an objective model that unites both the isolated fragments of our intuitions and causal chains. Very much like Cassirer, Weizsäcker expressed this result in terms of the failure of the possibility of the "objectifiability" of nature and concluded that quantum mechanics announced the end of the substantialist attitude toward nature. Even though Weizsäcker held that the classical presuppositions of picturability and causality still constitute the fundamental tools in quantum mechanics—since like Bohr he held that all understanding is to be expressed in classical language—Weizsäcker stressed that the failure was not to be taken lightly, for a "'worldview' has collapsed".[338]

Cassirer had a very similar standpoint. In the end, however, his reflections took a very different turn with respect to the question of the physical object. Cassirer tells us that the atom may be thought of as a small rigid sphere filling a definite amount of space. Even though this is allowed, he continued, the space-time representation collapses immediately when we consider the constitution of matter in terms of electrical fields. As a result, he said, the wave-attributes of matter thus necessitated a reorientation of the concept of mass-point.[339] This marked Cassirer's determination to seek besides the negative restrictions of our "visualizable thinglike representations" (*sinnlich-dingliche Vorstellungen*) (DI: p. 146, 150) also a positive affirmation of what the theory of quantum mechanics ultimately *is about*. This was for instance seen in Cassirer's appraisal of the ancient concept of the atom (*Atombegriffs*) which, he said, had found a more secure ground than it had ever done before. Moreover, he said, Bohr's concept of the atom did not dismiss Rutherford's theory (1911) but actually advanced it. (DI: p. 139)

---

338 Weizsäcker 1941a pp. 193-194. See also: Weizsäcker 1941b e.g. pp. 490, 497. Hernán Pringe has recently argued, partly on the basis of a critical analysis of Cassirer's views, that the quantum object cannot be a possible object of experience. (Pringe 2007 p. 230)

339 See for instance: DI: pp. 151, 196.

So, Cassirer agreed with Bohr and Weizsäcker that we must let go of a reality criterion based on the uniqueness or stability of nature, as it was for instance advocated by Ernst Mach.[340] Cassiser had already expressed this in 1921 with respect to relativity as a "lost unity of nature". (ET p. 415) Moreover, as we saw, we could for Cassirer also not speak of existence anymore in the sense of the classical demand of complete determination. As Weizsäcker formulated it—seemingly repeating Cassirer's conclusions in *Substanzbegriff und Funktionsbegriff* and *Determinismus*—we must instead turn our attention to the inner necessity of the new physics, "not in the form of a connection to outdated images, but by understanding their function in the greater process of our cognition."[341] Yet, this could not be our sole goal. A denial of the possibility of a construal of a physical object based on the objective reality of measurement results undermined on Cassirer's view the objectivity of a theory as a whole.

Given that the object is the *telos* of both philosophical and scientific analysis, Cassirer's proposal of a reorientation toward "the behavior of physical systems" was the expression of the fundamental requirement of an attachment to a *fundamentum in re*. Cassirer's proposal was by no means an easy task. Frank was even of the opinion that Cassirer was completely reluctant to say what exactly "describes the states of a physical system".[342] Granted, *Determinismus* did not offer a firm grip on what empirically defined them. Moreover, it was by no means clear how an "indirect hypostasis" or "mediated reification" as the believe in the existence of the structures laid down by the lawful relations of the theory was to proceed without considering the existence of individual elements. Still, I believe, Cassirer's suggestion to consider instead of the old concepts the "behavior of physical systems" responded to the apparent negative situation that a *fundamentum in re* was ultimately impossible.

---

[340] Stöltzner 1999 p. 86.

[341] Weizsäcker 1941a p. 194.

[342] Frank 1937 p. 74.

11 WHY CASSIRER WROTE ON QUANTUM MECHANICS

Important concepts were at stake for Cassirer. To end on a theoretically somewhat lighter tone albeit a historically grimmer one, I will here seek an answer to the question what motivated Cassirer to write against the introduction of a notion of indeterminism. The notion was supposed to give rise to the “most dangerous equivocations”, Cassirer said. (DI p. 111: p. 89) Of course, Cassirer primarily wanted to critically test the epistemological thesis of functionalism and move toward a generalized principle of causality and a functional account of the physical object. Somewhat like Planck, Laue and Einstein, who were arguable supporters of a more traditional worldview, which in the nineteenth century had depended on the concepts of determinism and causality, Cassirer felt responsible, as one of the last representatives of an influential current in neo-Kantianism, to defend his interpretation of these concepts against recurrent “overinterpretations”.

Yet, besides these theoretical concerns, Cassirer also appears to have been motivated at least partly by considerations of morality and freedom. After all, the last chapter of *Determinismus* contained some important remarks on the nature of practical reason (*Praktische Vernunft*). Even though the characteristic similarity between practical reason and theoretical reason was usually expressed more tacitly than openly, its importance for Cassirer will be obvious after this chapter. First, I will shortly describe some of Cassirer’s struggles during the period in which he wrote *Determinismus*. Thereafter I will answer the question why the notion of indeterminism was considered by Cassirer to be a dangerous thesis.

11.1 National Socialism

In a lecture given at the University of Gothenburg (*Göteborgs Högskola*), Cassirer’s grandson, Peter Cassirer, shared with us some of the stories he has been told about his grandfather.[343] Cassirer and his family were granted asylum in Sweden in 1935 and it appears that the turmoil of the 1930s took its toll, also on the “Olympian” Cassirer, as he was called during his student time in Marburg.[344] It thus appears that Cassirer had little opportunity to promote and defend the content of his newly published book.

> *Cassirer had written* [Determinismus und Indeterminismus] *during his stay in England. It happened at that time that my grandmother* [Toni Cassirer] *fell ill and my grandfather for once was forced to go into the kitchen, a place I think he was not very familiar with.*[345]

[343] His lecture is also partly based on his reading of the biography written by the philosopher’s wife, Toni Cassirer. See: *Mein Leben mit Ernst Cassirer* (Hildesheim: Gerstenberg (1981)).

[344] Peter Cassirer: 'On my grandfather Ernst Cassirer'. The nickname alluded both to Cassirer’s love for ancient Greek philosophy and mythology and his extreme capacity to memorize.

[345] Ibid. The story continues: “He made some tea, which endeavour he accomplished. But as he was to warm the milk he put the bottle directly on the stove with a consequence that he theoretically should

In January 1938 Cassirer wrote Kurt Goldstein about his worries regarding Toni's health. Apparently, Toni was still ill: "*Auch ich hatte zu persönlichen lagen keinen Anlaß, wenngleich mich natürlich die Zukunft der Kinder und Tonis stets unsichere Gesundheit oft sehr schwer bedrückt hat.*" (ECN 18: 22-1-1938) Additionally, Cassirer intended to present and discuss the content of *Determinismus* visiting international conferences, but, as far as the evidence shows, Cassirer did not attend any major conference at that time. Already before its publication Cassirer was invited by Otto Neurath, who was in exile in The Hague, for the *Second International Congress for the Unity of Science* in Copenhagen in June 1937. (ECN 18: 20-4-1936) The congress would start in Bohr's residence and its committee included Bertrand Russell, Rudolf Carnap, Schlick and many others. The theme of the conference was stated as "the problem of causality" and would have been perfectly timed for Cassirer's new book, particularly in relation to the somewhat Kantian theme of the unity of science. Like Bohr, Cassirer was supposed to give a lecture on causality, but unfortunately he had to cancel the whole arrangement.[346]

As we learn from the letters in the years approaching the German invasion of Poland, also Cassirer was at times exhausted. His reason, in contrast, was not sickness but the intensification of his correspondence with relations in Germany. Often he and Toni were asked to provide the ones who stayed behind with advice. They worked hard to answer all their letters. It appears that Cassirer was haunted by the happenings in Germany:

> *In the USA Ernst Cassirer wrote his two last and most popular books,* An essay on man *and* The myth of the state. *His state of health had deteriorated under the pressure of the political events and my grandmother writes that she was in constant fear when her husband did not return on scheduled time which happened now and then when Cassirer became totally absorbed by some idea he wanted to pursue in a library. On the 12th of April 1945 the radio reported that Franklin Roosevelt died calmly in his sleep. 'If you promise me to die in the same way', my grandmother said to Ernst Cassirer, 'I grant you to die tomorrow'. As the obedient husband that he was, he did so.*[347]

It is said that Cassirer hardly had a will to enter into strong discussions let alone to get involved in open intellectual rivalry. At least one major exception was the essay on Nazism which he supposedly intended to write during his time in Oxford. Toni Cassirer took it as her task to prevent Cassirer from writing it considering the dangers for their, particularly Jewish, friends

---

have been able to foresee with regard to his newly published book! My grandmother was so happy for that incident that she recovered immediately."

346 In the announcements in *Erkenntis*, Cassirer's presentation was entitled "*Zur Kausalproblem*". (See: Anonymous 1936) Cassirer had to give way to receiving an honorary degree in law from the University of Glasgow. (ECN 18: 12-5-1936) Neurath invited Cassirer for a second attempt on the fourth edition of the congress in July 1938 in Cambridge. (ECN 18: 15-1-1938) But in vain, for unclear reasons Cassirer also didn't make it to the fourth edition. (ECN 18: footnote 392) A possible reason might have been the difficulty for Cassirer to travel to France from Sweden as Germany was approaching war.

347 Peter Cassirer: 'On my grandfather Ernst Cassirer'.

and relatives still in Germany. Cassirer generally felt heavily convinced that the “baleful influence of German thinkers as Heidegger and Spengler” should not be discounted.[348] Spengler’s passive attitude and fatalism typically enfeebled and slowly undermined what Cassirer called “the forces that could have resisted the modern political myths”:

> *A philosophy of history that consists in sombre predictions of the decline and inevitable destruction of our civilization and a theory that sees in the* Geworfenheit *of man one of his principle characters have given up all hope of an active share in the construction and reconstruction of man’s cultural life. Such philosophy renounces its own fundamental theoretical and ethical ideals. It can be used, then, as a pliable instrument in the hands of political leaders.*[349]

Observing Cassirer’s situation from an anthropological perspective, it has been argued that Cassirer responded to an incessant historical crisis: an increasingly specialized and fragmented reality of scientific practice and theory, an apparent de-humanization of knowledge, the technological and industrial realities underlying the horrors of the previous world war, and, of course, a distrust of “the foreign” (*das Fremde*). In contradistinction with the deeply rooted preoccupation with the authentic (*das Eigene*), expressed also in Heidegger’s philosophy, Cassirer’s was an attempt to universalize science and philosophy and particularly, to battle the dangers for civilization of an “atavistic nationalism” and “orchestrated collective sentiment”.[350]

11.2 Wissen ist Pflicht

Cassirer’s professorship in Hamburg was already marked by a deep interest in political matters. Cassirer for instance took much interest in defending the value of democracy. Cassirer was unfortunately not always effective in conveying the urgency of the matter, as his reasoning was often considered to be far too abstract and distanced. But in one of his rectorial speeches in the early 1930s in Hamburg Cassirer defended with an unusual clear voice that “*Wissen ist Pflicht*”. Herewith he stressed the neglected responsibility and duty of intellectuals in a Weimar Germany that gradually slipped into absolute dictatorship. His clear declaration could even be interpreted as an exhortation to act.[351]

In his article on Heisenberg’s uncertainty relations, Laue expressed a similar concern as he wrote of the scientific pessimism that possibly resulted from the vain search for an absolute causal law in nature:

> *Wann soll die Kausalität als ‘empirisch bewiesen’ gelten? Etwa, wenn das letzte naturwissenschaftliche Problem restlos gelöst ist? Der Zustand durfte nie eintreten. Es gab freilich eine Zeit—sie liegt einige Jahrzehnte zurück ... als man die Beantwortung aller noch offenen physikalischen Fragen im Wesentlichen abgeschlossen ansah. ...*

[348] Curthoys 2011 p. 26.
[349] Cassirer 1946 p. 293.
[350] Curthoys 2011 p. 27.
[351] Peter Cassirer: 'On my grandfather Ernst Cassirer'.

Dafür verfällt man jetzt in den nicht minder unkritischen Pessimismus: Die Aufgabe der Physik ist überhaupt unlösbar.[352]

Laue said that concluding the failure of causality was a sign of a deep "*Kulturpessimismus, der eine Grundstimmung unserer Zeit bildet.*" Just as Cassirer proclaimed, scientific rationality should strive for things higher than the spur of the moment: "*Mit ihm sich zu befassen, ist aber nicht mehr Amt des Naturforschers; seine Wissenschaft steht über allen menschlichen Stimmungen*."[353]

11.3 Strict scientific argumentation

Frank applauded to Cassirer's "strict scientific argumentation" when it came to the ethical implications of quantum mechanics. Contrary to what Frank wrote on Cassirer's idealistic remnants—something he regarded as unscientific—he praised Cassirer's conclusion about a strict separation between ethical questions and questions of natural law.[354] Frank even highlighted that Cassirer saw the possibility of drawing an analogy between the quantum mechanical complementarity—most prominently, the duality of the particle-wave nature of matter—and the perspectival change when switching from a natural scientific point of view to an ethical or esthetical point of view. Indeed, without explicitly mentioning the notion complementarity, Cassirer did shortly took note of the similarity:

What modern physics has taught us is the fact that the change of standpoint which we have to make whenever we move from one dimension to another, whenever we exchange the world of science for that of ethics, art, etc. is not confined to this type of transition alone. The manifold of perspectives which open up before us has its counterpart within the scientific realm itself. (DI: p. 212)

Cassirer suggested that having a "duality of description" as such was nothing new. Physical complementarity was a great achievement because it showed that modern physics itself abandoned "the hope of exhaustively presenting the whole of natural happening by means of a single strictly determined system of symbols." (DI: p. 212) Cassirer herewith wished to emphasize what has been described as the fundamental attitude of "accepting basic dualities without straining for their mutual dissolution or reduction."[355] This was one of the fundamental attitudes of Cassirer's *Philosophie der symbolischen Formen* (1923-1929).

---

[352] Laue 1934.

[353] Ibid.

[354] Frank 1938 p. 79-80. Frank believed that Cassirer's proposal to strictly separate questions of moral freedom from questions about the "lawfulness of nature" (*Naturgesetzlichkeit*) was very similar to that of Schlick's 'Fragen der Ethik' (1930). Moreover, the positivist manifesto *Wissenschaftliche Weltauffasung der Wiener Kreis*, published and written also with the help of Frank, called for the unity of science and society based on universal standards of scientific rationality. See: Hahn et al. 1929.

[355] Holton 1970 p. 1049. This attitude was somewhat in contrast with Bohr's view where he held that the overlay of complementary descriptions provided an *exhaustive* understanding of nature. (p. 1018) See for example: ET p. 418 and DI: p. 190.

Like Frank, also other physicists reported to be entirely at ease with Cassirer's conclusions on ethics. Absolutely no critique on these passages has been found.[356] Like in his letter to Cassirer, Born stated in the appendix to his much later "Waynflete Lectures" (1948) that his ideas on the ethical consequences of indeterminism were fully in line with Cassirer's. Born stated to believe that there "is no unique image of our whole world of experience."[357] Moreover, he concluded with stating that his satisfaction with Cassirer's book stemmed from the insight that the philosophical importance of quantum mechanics lay not so much with the question of indeterminism but with what he called the "possibility of several complementary perspectives."[358] Wind also applauded to the centrality of the variety of philosophical perspectives within Cassirer's work. He even held it to be a central claim of the book: "*um ganz allgemein die 'Mannigfaltigkeit der Perspektiven' als philosophische Forderung hinzustellen*." (ECN 18: 6-4-1937)

Cassirer took much importance in Kant's dictum that "no augmentation but only a distortion of the fields of knowledge results when we permit boundaries to run into each other." (DI: p. 197) Reason, for Kant, must divide its labour; it is imperative that the different sciences are sufficiently demarcated from one another. Born fully agreed and quoted Cassirer at length:

> *From the significance of freedom, as a mere possibility limited by natural laws, there is no way to that 'reality' of volition and freedom of decision with which ethics is concerned. To mistake the choice* [Auswahl] *which an electron, according to Bohr's theory, has between different orbits, with a choice* [Wahl] *in the ethical sense of this concept, would mean to become the victim of a purely linguistic equivocality. To speak of an ethical choice there must not only be different possibilities but a conscious decision about them. To attribute such acts to an electron would be a gross relapse into a form of anthropomorphism…*[359] (DI p. 259:)

The fate of the individual person is left completely undetermined (*unbestimmt*) by the statistical approach of quantum mechanics, Cassirer declared. These "freedoms" were of a wholly different kind. When Antoni took note of this apparent confusion, he stated that Cassirer had even been offended by the various disturbing anthropomorphisms: "For what ever science would be one that cheerfully, with a Nietzschean intoxication, admitted the disorder, the will and the irrationality of nature?"[360] Moreover, if one would embrace a metaphysical indeterminism, the possibility of freedom consequently perishes. This was so for Cassirer

---

[356] Laue, for instance, stated to fully agree with Cassirer's thoughts on the relation between ethics the uncertainty relations in the last chapter of *Determinismus*. (ECN 18: 4-4-1937) Born also applauded to Cassirer's conclusion. (ECN 18: 19-3-1937)

[357] Born 1949 p. 208.

[358] Ibid.

[359] Ibid. This is probably Born's own translation. I added the original formulations of what is translated as "choice".

[360] Antoni 1938. Antoni's remark was probably a response to Bohr's and Heisenberg's view: An inherent "'irrationality' which is brought in with the quantum postulate according to Bohr." (Bohr 1927 p. 52, 91)

because like knowledge, freedom is based upon a “mode of determination” which is not to be “built on the ruins of nature’s conformity to law; rather it joins the latter as a correlative and complement.” (DI: p. 203)

11.4 Moral freedom

It should now be clear that Cassirer’s concerns lay not solely with the possibility of science. Not only did Cassirer claim that there were no conclusions to be drawn of quantum mechanics with respect to the realm of ethics and the free will. Even stronger, the equivocations of indeterminism were also dangerous in a moral sense.[361] Contrary to the view that physics and ethics are strictly demarcated explained above, the entry on Cassirer in the *Deutsche Biographische Enzyklopädie* introduces *Determinismus* as the ethical foundation for his philosophy of culture.[362] Although at first the connection might not be obvious or even seem mischievous, *Determinismus* does contain a hidden relation to ethics. Quantum mechanics seemed to be on the verge of being indeterministic. For some, we even stumbled upon a fundamental “arbitrariness” or “capriciousness” (*Willkürlichkeit*) of nature. But when allowing this, Cassirer observed, physics seemed to open the doors to what he believed to be a perverted notion of freedom, “a *liberum arbitrium indifferentiae*, a state of freedom which was hardly distinguishable from caprice [*Willkür*].” (DI p. 112: p. 89)

Accordingly, Wind stressed in his letter to Cassirer that he fully agreed that the idea of the “relaxation of the laws of nature” represented for the realm of ethics a “fatal gift” (*Danaergeschenk*).[363] (ECN 18: 6-4-1937) (DI: p. 203) With the introduction of a metaphysical indeterminism the possibility of responsibility would come to fall completely. Freedom understood as “causelesness” would “not leave room for that moral responsibility the possibility and necessity of which ethics aims to prove. ... Only an action ‘grounded’ in some way can be considered a responsible action, and the value ascribed to it depends on the type, on the quality of these grounds and not on their absence.” (DI: p. 203) However, Wind asked, when the fate of history offers us such a fatal gift, are we in a position to deny it? Does statistical causality not imply a much more complex view of nature and in turn the necessity of a refinement of Kant’s ethics? Should we not meet with the infringements upon physical determinism, no matter how infinitesimal?[364] (ECN 18: 6-4-1937)

Cassirer’s view seemed to suggest that there was, after all, some sort of relation between the theoretical and the practical. Bohr had already mentioned the discussions on free will and causality in 1929, but with his vision of complementarity, he had spoken vaguely. He likened the two concepts to the subjective and objective respectively: “the feeling of volition and the demand for causality are equally indispensable elements in the relation between subject

---

[361] Besides Wind (ECN 18: 6-4-1937) and Antoni (1938) no other commentator appears to have recognized this move.

[362] The entry is written by Heinz Paetzold, a german philosopher who specialized in Cassirer’s writings. See: Paetzold 2005.

[363] The “fatal gift” was noted by Antoni (1938).

[364] Recall that Wind had noted that his mentor Cassirer had taught that all revolutions start with the infinitesimal.

and object which forms the core of the problem of knowledge."[365] Indeed, Cassirer affirmed, "the structure of our theoretical as well as ethical world depends on the permeation and correct complementation of each by the other." (DI: p. 205)

11.5 Kant's autonomy

Let's shortly have a look at how Kant perceived the ideas of freedom and responsibility. Kant had explicitly defended that the central problem of freedom is not the question whether the "cause" of my action is within me or not. The real issue is whether it is in my control at this moment. All intentional volition is an immediate effect the self, which is to be understood as a causally undetermined absolute thing in itself. Its ground lies out of space and out of time, the latter, recall, being centrally connected to causality. Nonetheless, Kant also paradoxically found that freedom is not to be equated with a mere causelessnes. He said that my *noumenal* self is to be regarded as "a cause independent of all sensibility".[366] Equating moral freedom with causelessness and thus with "indeterminacy" or "indeterminabiltiy", Cassirer wrote, is merely a negative designation. (DI: p. 198) No matter what kind of external influences act on a person, Kant said, "every action … is to be regarded in the consciousness of his intelligible existence as nothing but the consequence … of his causality as a *noumenon*." [367] The will is therefore a cause that is uncaused by the laws of nature in accordance with which experience is constituted.

Like Kant, Cassirer was also of the opinion that—notwithstanding the strict demarcation between spatiotemporal causes and *noumenal* "uncaused causes"—all science, and in our case quantum mechanics, shows something essential about the ethical intellect or what Kant had called "practical reason". Put crudely, the laws of quantum mechanics are wholly external to our voluntary decisions. Ethics cannot affect scientific results and its premises, nor can such a relation be established *vice versa*. Moreover, that for Cassirer quantum mechanics was based on causality and determinate relational structures fitted remarkably well with the Kantian outlook on freedom.

Let's have a look at the duality between "autonomy" and "heteronomy". "Every rational being, according to Kant, has two points of view from which he can regard himself and recognize laws governing his actions" (DI: p. 202) First, there is heteronomy: When rational beings find themselves subject to laws of nature, they are unfree. Rational beings necessarily will and act in accordance with the rules or laws depending on the external world. Second, the self also belongs to an intelligible world in which it finds itself under laws that are independent of nature and have their foundation not in experience but in reason alone. Kant called this "giving the law to oneself" autonomy: freely willing and acting in accordance with a universal rule or practical law established by the free use of reason. Not surprisingly, Cassirer took over Kant's concern with freedom as autonomy: "man acts freely who acts with regard to the world of Ideas; and a free subject is the one who is aware of the Ideas and in virtue of them can survey the whole realm of phenomena, of spatiotemporal appearances, and can recognize it in all its determinateness." (DI: p. 199-200)

---

[365] Bohr 1929 p. 117. See also: Holton 1970 pp. 1031, 1048.
[366] Kant 1996 5: 97–98.
[367] Ibid.

Freedom is thus not simply understood in a positive or negative sense, as the absence of external restrains or the permission, ability or duty to do something. The only way to act freely, Kant held, is to base oneself upon formal rules. Such rules, or maxims, as he called them, are provided by the "categorical imperative" or "moral law", the latter being the absolute requirement of pure practical reason in accordance with which one acts morally. The command of Kant's categorical imperative applies to everyone unconditionally—act in such a way that the maxim of your will could always hold at the same time as a principle of a universal legislation. Freedom and morality reciprocally imply one another. On the one hand, the moral law needs freedom, trusting that it is a "fact of reason".[368] On the other hand, the moral law is thus understood as "the *ratio cognoscendi* of freedom, since it is through the consciousness of the law that one becomes aware of one's freedom".[369] What is most important in our case, is that instead of heteronomy—being influenced by the senses or contingent desires and basing oneself on contingent hypothetical imperatives—the moral law provides universal rules of reason that apply no matter what my goals and desires may be at that moment. Thus—and this was of crucial importance with respect to the discussion on determinism and indeterminism in Cassirer's arguments—the moral law follows from the idea that willing is to act on the basis of a maxim, a rule of action. It explains what you are doing and for what reason you do it.

There is no other way to be free than through the determinateness of law, which, recall, was according to Cassirer also essential to all scientific knowledge. It was unacceptable for him to suggest that with quantum mechanics nature turned out to be fundamentally random or *Willkürlich* for the reason that it contradicted the fact that reason must base itself upon determinate rules. Indeterminism was a sign of the unfree, because in order to be free, thought must—instead of basing oneself on mood or caprice—continuously determine its maxims of universal legislation. Like all absolutes, the free will was also subject to the "transcendental insight". Cohen said that also the free will is set as a task: "*der Wille ist uns nicht gegeben, sondern aufgegeben*."[370] In sum, practical and theoretical reason thus showed a fundamental affinity.

Frank, Born, Laue and Nagel, all missed this "false bottom" in Cassirer's writing, regarding it a very satisfactory outcome that for ethics, as Nagel put it, the "import is nil".[371] We are left feeling that in *Determinismus* Cassirer obscured a complex and easily misunderstood relation that was nevertheless of crucial importance for him. For Cassirer, there was more at stake than just the Kantian spirit, namely the possibility of rational thought and action as such. Indeterminism did not provide a fertile ground for rationality. For that reason, it makes sense to say that Cassirer's treatise on quantum mechanics also functioned to legitimize his critique of the existing political, moral or technological order and expressed concerns about a general cultural malaise.[372]

---

[368] See for instance: Kant 1996 5: 31, 42, 47, 55.

[369] Allison 1983 p. 310.

[370] Cohen 1914 p. 51. (See footnotes 42, 89, 301 and 302)

[371] Nagel 1938. The exception is Weizsäcker, who in his review completely disregarded *Determinismus'* last chapter on ethics.

[372] This is a paraphrasing of a line of Sigurdsson's *Einsteinian Fixations*: Sigurdsson 1992 p. 581. Sigurdsson argues that Hentschel (1990) failed to recognize that many advocates of "relativism" used

As Cassirer stated already in *Freiheit und Form* (1916), all derived purposes and goals desire and demand the idea of something that is an "end in itself" (*Selbstzweck*). Likewise, we cannot achieve certainty about anything *other* before we attain knowledge of principles that are in and by themselves general and necessary, that is, of what is a priori. Therefore:

> *... the problem of the a priori and the problem of freedom [are] merely different expressions of one and the same foundational requirement. The autonomy of the will and the autonomy of thought entail one another and reciprocally point to one another.*[373]

Like Kant, Cassirer found that no understanding of freedom can be equated with causlessness or indeterminateness, "acausality" or indeterminism. The metaphysician denying this central requirement with a thesis of indeterminism is an unhappy guest, for his proposal is redundant and unwanted. For that reason, Cassirer proposed that its hosts should answer "I don't need it, and it's not enough anyway":

> *Even if a solution to the riddle could be offered in the form of some physical indeterminism,* [the student of ethics] *would have to reject it with the words Queen Christina of Sweden is said to have used when she renounced crown and kingdom:* non mi bisogna e non mi basta. (DI: p. 207)

Einstein's relativity theory and generally the "prestige of science" to amplify their political or ethical positions. As I argue, Cassirer did not take the common road of cultural relativism or, in 1937, of indeterminism. Nonetheless, Cassirer's last chapter was ethically and politically charged.

[373] Cassirer 1916 p. 166 (original edition pp. 246-247). See also: DI: p. 203.

12 CONCLUSION

Cassirer did not acknowledge head on what the physicists Laue, Born, Frank, Weizsäcker and Pettersson in their comments regarded as the incompatibility between, on the one hand, the classical and Kantian notions of causality and determinism and, on the other hand, the laws of quantum mechanics. First of all, causality was violated in the sense that the laws of nature could no longer be seen as *necessary* rules in virtue of which effects are always produced when the causes are present. Secondly, determinism was violated in the sense that the fundamental equations of the theory do not provide us with *unique* solutions and as a result exclude the possibility of a *perfect* predict of future or past events. Instead of therefore drawing the conclusion that causality lacked application and that physical reality was indeterministic, Cassirer proposed a specific reorientation of the debate. Rather than focussing on the indeterminateness of the individual elements or properties related in the laws of physics, Cassirer suggested to focus on the determinacy of the laws themselves. Cassirer's work showed how the thesis of determinism was deeply intertwined with the determinacy of experience. In short, a notion of physical determinism was intrinsically depended on the possibility of the process in which thought arrives at a determinate content. This was expressed most clearly in Cassirer's request to formulate a priori causality as the law-abiding character of experience. As such, the regulative principle harboured the possibility of objectivity as the ability to establish a unity between principles, laws and measurement. As we saw, Cassirer's demand also re-secured the possibility of autonomy.

However, as had become clear also with the debate on relativity, Cassirer's philosophy was by no means a doctrine that was capable of either a direct confirmation or refutation in a straightforward way. This wholly depended on the future progress of science, so to say. Moreover, the principles of his philosophy were, of course, aimed to establish eternally valid presuppositions of the scientific intellect. As such, they were taken to be irrefutable by science itself, at least in direction and spirit. However, this attitude may at times have been interpreted as reticence, or worse, as reluctance.

All physicists found that Cassirer was unwilling to specify his statements and demanded a more rigorous treatment of the empirical findings. Indeed, the title of Cassirer's book ambiguously highlighted that it essentially communicated a historical study and therefore might not have much say in contemporary physical controversies. Moreover, it often remained to be a question what for Cassirer the exact status of a priori causality was with respect to other regulative or constitutive principles of science. The principle of causality was perhaps identical with the principle of the unity of nature, as his letter to Schlick suggested. That would mean—and so it seems—that like the unity of nature, causality was the summit of Cassirer's a priori. This would mean, in other words, that orderliness according to law was for him the most central methodological presupposition of theoretical reason. Nonetheless, Cassirer rarely resolved such questions directly, neither in *Determinismus* nor in other writings. This often resulted in unreleased tensions.

Because classical principles—think of "complete determination"—were usually not rigorously sacrificed but only taken up in a more general synthesis—think of "determinability"—Cassirer often left the reader hanging in the air. Even though Cassirer had reasons for doing so, it has for the purposes of this study sometimes been necessary to subtly press his writings and critically demand of them that they come clean as to what principles are bought into and what principles must eventually be sacrificed. In doing so, it became clear that Cassirer did for an important part take into account what Weizsäcker had called the needs of the physicists. Cassirer argued against a cosmological determinism and claimed that quantum mechanics loosened the classical and Kantian demand that we can establish a precise number for every observable. In this sense, Cassirer said that physics was dealing with physical systems that were not completely determinate. As result of his somewhat opaque style of writing, however, this claim was not always evident. Moreover, Cassirer's philosophical interests lay with the universal demands of scientific reason and not so much with empirical considerations. This meant that Cassirer's methodology was meant to establish the continuity and unity of the historical development of science. For that reason he occasionally seemed to surpass the explosiveness with which the old worldview was violated.

At that time, the "Olympian" Cassirer was one of the lonely few defenders of a neo-Kantian philosophy of science. He was its mean representative and had even been one of Kant's most progressive and critical followers. Moreover, Cassirer was one of the first philosophers in the neo-Kantian camp to write on quantum mechanics. This meant that there was much at stake. It is therefore fitting to recall that Cassirer admitted to Schlick that he spoke in a language that was perhaps foreign to scientists. Schlick's closely related views of logical positivism probably encountered much less resistance, he said, for their formulations stood much closer to the experience of scientists. A mediating position between philosophy and science could therefore nevertheless be maintained, Cassirer concluded.

Though many letters of Cassirer have been preserved, no responses to any of the criticisms have been found. Even though Cassirer wished to publish an appendix with Margenau to update the development of the causality problem, no subsequent publication appeared. That Cassirer was not present at the congress for the Unity of Science in Copenhagen symbolizes both a failed attempt to actively engage in dialogue with those who disagreed and the unfortunate fact that Cassirer was at times powerless to change this. This non-engagement had also been the case with the debate on relativity with Schlick sixteen years earlier. Cassirer could easily have clarified why he took a stance toward the foundations of physics that was wholly different from those of logical positivists and the physicists. However, this time in the 1930s, Kantianism seemed to fade out and Cassirer was in exile in Sweden and in the United States. Even though he remained to study the results of the newest physics, Cassirer understandably became more and more absorbed by his writings on issues of mythology, humanity, politics, and freedom.

BIBLIOGRAPHY

Anonymous (1936), 'Zweiter internationaler Kongress für Einheit der Wissenschaft', *Erkenntnis,* 6 (1), 137-38, 275-277.

Anonymous (1939), 'Books Received', *Erkenntnis,* 8 (1/3), 187-190.

Allison, Henry E. (1983), *Kant's Transcendental Idealism: An Interpretation and Defense* (New Haven and London: Yale University Press).

Antoni, Carlo (1938), 'Review: Ernst Cassirer, Determinismus und Indeterminismus in der modernen Physik', *Giornale critico della filosofia italiana,* 19, 155-159.

Bohr, Niels (1926), 'Atomtheorie und Mechanik', *Die Naturwissenschaften,* 14 (1), 1-10.

——— (1927), 'The Quantum Postulate and the Recent Development of Atomic Theory', in: *The Philosophical Writings of Niels Bohr,* 1 (Cambridge: University Press), 52-91. Originally in: *Nature,* 121 (1928), 147-158.

——— (1929), 'The Quantum of Action and the Description of Nature', in: *The Philosophical Writings of Niels Bohr,* 1 (Cambridge: University Press), 92-101.

——— (1935), 'Can Quantum-Mechanical description of Physical Reality be Considered Complete?', *Physical Review,* 48, 696-702.

——— (1937), 'Causality and Complementarity', *Philosophy of Science,* 4 (3), 289-298.

——— (1948), 'On the notions of causality and complementarity', *Dialectica* (2), 312-319. In: *Collected Works*, 7, 25-37.

Born, Max (1926), 'Quantenmechanik der Stoßvorgänge', *Zeitschrift für Physik,* 37 (12), 863-867.

——— (1927), 'Quantenmechanik und Statistik', *Die Naturwissenschaften* 15 (10), 238-242.

——— (1949), *Natural Philosophy of Cause and Chance* (Oxford: Clarendon Press).

Cassirer, Ernst (1907a), 'Kant und die Moderne Mathematik', *Kant-Studien,* 12, 1-40.

——— (1907b), *In der Philosophie und Wissenschaft der neuern Zeit,* Das Erkenntnisproblem in der Philosophie und Wissenschaft der neuern Zeit, 2 (Darmstadt: Wissenschaftliche Buchgeselschaft).

——— (1910), *Substanzbegriff und Funktionsbegriff: Untersuchungen öber die Grundfragen der Erkenntniskritik* (Berlin: Bruno Cassirer). Translated by Swabey & Swabey as: *Substance and Function & Einstein's Theory of Relativity* (Chigaco: Open Court (1923)).

——— (1916), *Freiheit und Form: Studien zur deutschen Geistesgeschichte,* in: R. Schmücker (ed.) *Gesammelte Werke Hamburger Ausgabe* (ECW: 7) (Hamburg: Felix Meiner (2001)).

——— (1918), *Kants Leben und Lehre* (Berlin: Bruno Cassirer).

——— (1920), 'Philosophische Probleme der Relativitätstheorie', *Die Neue Rundschau,* 21, 1337-57.

——— (1921), *Zur Einstein'schen Relativitätstheorie* (Berlin: Bruno Cassirer). Translated by Swabey & Swabey as: *Substance and Function & Einstein's Theory of Relativity* (Chigaco: Open Court (1923)).

——— (1927), *Erkenntnistheorie nebst den Grenzfragen der Logik und Denkpsychologie*, in: T. Berben (ed.), *Gesammelte Werke Hamburger Ausgabe* (ECW: 17) (Hamburg: Felix

Meiner (2004)).
——— (1929), *Philosophie der symbolischen Formen III: Phänomenologie der Erkenntnis.* (Berlin: Bruno Cassirer). Translated as: *The Philosophy of Symbolic Forms III: The Phenomenology of Knowledge* (New Haven: Yale University Press (1957)).
——— (1937), *Determinismus und Indeterminismus in der modernen Physik: Historische und systematische Studien zum Kausalproblem* (Göteborg: Högskolas Årsskrift). Translated by O. T. Benfey as: *Determinism and Indeterminism in Modern Physics: Historical and Systematic Studies of the Problem of Causality* (New Haven: Yale University Press (1956)).
——— (1944), *An Essay on Man: An Introduction to a Philosophy of Human Culture* (New Haven: Yale University Press).
——— (1946), *Myth of the State*, in: M. Lukay (ed.), *Gesammelte Werke Hamburger Ausgabe* (ECW: 25) (Hamburg: Felix Meiner (2007)).
——— (1993), *Erkenntnis, Begriff, Kultur,* R.A. Bast (ed.) (Hamburg: Felix Meiner Verlag).
——— (1999), *Ausgewählter wissenschaftlicher Briefwechsel*, in: K. C. Köhnke, J. M. Krois, O. Schwemmer (ads.), *Nachgelassene Manuskripte und Texte* (ECN: 18) (Hamburg: Felix Meiner (2009)).
——— (2010), *Vorlesungen und Vorträge zu philosophischen Problemen der Wissenschaften 1907 – 1945*, in: J. Fingerhut, G. Hartung, R. Kramme (eds.), *Nachgelassene Manuskripte und Texte* (ECN: 8) (Hamburg: Felix Meiner).
Cassirer, Peter 'On my grandfather Ernst Cassirer'. URL: http://web.telia.com/~u31252427/ecengl.htm (21-10-2014).
Cei, Angelo & French, Steven (2009), 'On the Transposition of the Substantial into the Functional: Bringing Cassirer's Philosophy of Quantum Mechanics into the Twenty-First Century', in: Bitbol Michel et. al. (eds.), *Constituting Objectivity: Transcendental Perspectives on Modern Physics*, The Western Ontario Series in Philosophy of Science, 74 (Paris: Spinger), 95-116.
Coffa, J. Alberto (1991), *The Semantic Tradition from Kant to Carnap: To the Vienna Station*, Linda Wessels (ed.) (Cambridge: University Press).
Cohen, Hermann (1871), *Kants Theorie der Erfahrung* (Berlin: Ferdinand Dümmler).
——— (1883), *Das Princip der Infinitesimal-Methode und seine Geschichte: ein Kapitel zur Grundlegung der Ekenntnißkritik* (Berlin: Ferdinand Dümmler).
——— (1902), *System der Philosophie: Logik der reinen Erkenntnis* (Berlin: Bruno Cassirer).
——— (1914), *Begründung der Ethik Erster Teil: Methode und Prizipien* (Bern: Cemach Feldstein).
Curthoys, Ned (2011), 'Ernst Cassirer, Hannah Arendt, and the twentieth century revival of philosophical anthropology', *Journal of Genocide Studies,* 13 (1-2), 23-46.
Daston, Lorraine & Galison, Peter (2007), *Objectivity* (New York: Zone Books).
Einstein, Albert (1929), 'The new field theory', *The Times* (4-2-1929), 13-14.
Ferrari, Massimo (1995), 'Ernst Cassirer und Pierre Duhem', in: E. Rudolph & B.-O. Küppers (eds.), *Kulturkritik nach Ernst Cassirer* (Hamburg: Felix Meiner), 177-196.
——— (2009), 'Is Cassirer a neo-Kantian Methodologically Speaking?' in: Rudolf A. Makkreel & Sebastian Luft (eds.), *Neo-Kantianism in Contemporary Philosophy* (Indiana: University Press).

Fleck, Ludwik (1929), 'Zur Krise der "Wirklichkeit"', *Die Naturwissenschaften,* 17, 425-30.
Forman, Paul (1971), 'Weimar culture, causality, and quantum theory: adaptation by German physicists and mathematicians to a hostile environment', *Historical Studies in the Physical Sciences,* 3, 1-115.
Frank, Philipp (1907), 'Kausalgesetz und Erfahrung', *Annalen der Naturphilosophie,* 6, 443–50. Translated as: 'Experience and the Law of Causality', in: Frank, Philipp, *Modern Science and its Philosophy* (Cambridge: Harvard University Press (1949)), 53–60.
——— (1932), *Das Kausalgesetz und seine Grenzen*, Frank & Schlick (eds.), Schriften zur wissenschaftlichen Weltauffassung (6) (Wien: Springer). Translated by M. Neurath & S. Cohen (ed.) as: *The Law of Causality and its Limits* (Dordrecht: Kluwer Academic Publishers).
——— (1936), 'Philosophische Deutungen und Mißdeutungen der Quantentheorie', *Erkenntnis,* 6, 303-317. Translated as: *Interpretations and misinterpretations of modern physics* (Paris: Hermann & Cie (1938)).
——— (1938), 'Bermerkungen zu E. Cassirer: Determinismus und Indeterminismus in der modernen Physik', *Theoria,* 4, 79-80.
——— (1941), *Between Physics and Philosophy* (Cambridge: Harvard University Press).
Frege, Gottlob (1980), *Philosophical and Mathematical Correspondence*, Brian McGuinness (ed.), Hans Kaal (tr.) (Chicago University Press).
Friedman, Michael (2000), *A Parting of the ways* (Open Court).
——— (2002), 'Carnap, Cassirer and Heidegger: The Davos Disputation and Twentieth Century Philosophy', *European Journal of Philosophy,* 10, 263-274.
——— (2005), 'Ernst Cassirer and the Philosophy of Science', in: Gary Gutting (ed.), *Continental Philosophy of Science* (Blackwell).
——— (2008), 'Ernst Cassirer and Thomas Kuhn: the neo-Kantian tradition in history and philosophy of science', *The Philosophical Forum*, 39 (2), 239-252.
Gawronsky, Dimitry (1949), 'Cassirer: his life and his work', in: Paul Arthur Schilpp (ed.), *The Philosophy of Ernst Cassirer*, The Library of Living Philosophers, VI (Evanston, Illinois: George Banta Publishing), 3-37.
Gower, Barry (2010), 'Cassirer, Schlick and 'structural' realism: the philosophy of the exact sciences in the background to early logical empiricism', *British Journal for the History of Philosophy*, 8 (1), 71-106.
Hahn, Hans (1933), 'Die Krise der Anschauung', in: Karl Menger (unmentioned) & Franz Deuticke (eds.), *Krise und Neuaufbau in den exakten Wissenschaften: Fünf Wiener Vorträge* (Leipzig, Wien).
———; Neurath, O.; Carnap, R. (1929) *Wissenschaftliche Weltauffassung der Wiener Kreis*, Veröffentlichungen des Vereins Ernst Mach (Vienna: Artur Wolf Verlag).
Heis, Jeremy (2010), 'Critical philosophy begins at the very point where logistic leaves off', *Perspectives on Science,* 18 (4), 383-408.
——— (2012), 'Ernst Cassirer, Kurt Lewin, and Hans Reichenbach', in: Nikolay Milkov and Volker Peckhaus (eds.), *The Berlin Group and the Philosophy of Logical Empiricism* (Boston Studies in the Philosophy and History of Science), 67-96.
——— (forthcoming a), 'Ernst Cassirer's Substanzbegriff und Funktionsbegriff', *History of Philosophy of Science.* URL: https://webfiles.uci.edu/jheis/www/Heis,%20S%20und%

20F%20TO%20APPEAR.pdf (21-10-2014).
——— (2014), 'Realism, Functions, and the A Priori: Ernst Cassirer's Philosophy of Science', *Studies in History and Philosophy of Science*, 48, 10–19.
Heisenberg, Werner (1927), 'Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik', *Zeitschrift für Physik,* 43 (3-4), 172-198.
——— (1958), 'The Copenhagen Interpretation of Qauntum Theory', *Physics and Philosophy* (New York: Harper & Borthers).
Hempel, Carl G. (1975), 'The old and the new ‘Erkenntnis’', *Erkenntnis,* 9, 1-4.
Hilbert, David (2000), 'Mathematical Problems', *Bulletin of the American Mathematical Society,* 37 (4), 407-436.
——— (1930), 'David Hilbert's Radio Address ', J. T. Smith (ed.), *Loci (2014)*.
Holton, Gerald (1970), 'The Roots of Complementarity', *Daedelus,* 99 (4), The Making of Modern Science: Biograhical Studies, 1015-1055.
Howard, Don (1994), 'Einstein, Kant and the origins of logical empiricism', in W.C. Salmon and G. Wolters (eds.), *Logic, Language, and the Structure of Scientific Theories: Proceedings of the Carnap-Reichenbach Centennial, University of Konstanz, 21-24 May 1991*, 45-106.
Ihmig, Carl-Norbert (2001), *Grundzüge einer Philosophie der Wissenschaften bei Ernst Cassirer* (Darmstadt: Wissenschaftliche Buchgesellschaft).
Jammer, Max (1989), *The Conceptual Development of Quantum Mechanics* (2nd edition), G. Holton et al. (ed.), The History of Modern Physics 1800-1950: 12 (Tomash Publishers).
Kant, Immanuel (1783), *Prolegomena to Any Future Metaphysics that Will Be Able to Come Forward as Science*, Paul Carus (tr.) James W. Ellington (rev.) (Indianapolis: Hackett).
——— (1992), *Lectures on Logic*, P. Gruyer & A. Wood (eds.) (Cambridge: University Press).
——— (1996), *Practical Philosophy*, P. Gruyer & A. Wood (eds.) (Cambridge: University Press).
——— (1998), *Critique of Pure Reason*, P. Guyer & A. Wood (eds.) (Cambridge: University Press).
Kaufmann, Fritz (1949), 'Das Verhältnis der Philosophie Cassirers zum Neukantianismus und zur Phänomenologie', in: Paul Arthur Schilpp (ed.), *Ernst Cassirer*, Philosophen des 20. Jahrhunderts (Berlin: Kohlhammer Verlag), 566-612.
Kaufmann, Felix (1949), 'Cassirer’s Wissenschaftstheorie', in: Paul Arthur Schilpp (ed.), *Ernst Cassirer,* Philosophen des 20. Jahrhunderts (Berlin: Kohlhammer Verlag), 118-145.
Kelsen, Hans (1939), 'Die Entstehung des Kausalgesetzes aus dem Vergeltungsprinzip: Vorbemerkung', *Erkenntnis,* 8 (1/3), 69-130.
Kitcher, Philip (1996), ‘Aprioristic Yearnings: *Kant and the Exact Sciences* by Michael Friedman’, *Erkenntnis*, 44 (3), 397-416.
Krois, John Michael (1987), *Cassirer: Symbolic Forms and History* (New Haven: Yale University Press).
Laue, Max von (1934), 'Über Heisenbergs Ungenauigkeitsbeziehungen und ihre erkenntnistheoretische Bedeutung', *Naturwissenschaften,* 22, 439-441.
Marx, Wolfgang (1975), 'Cassirer’s Symboltheorie als Entwicklung und Kritik der Neukantianischen Grundlangen einer Theorie des Denkens und Erkenntniss', *Archiv für Geschichte der Philosophie,* 57 (3), 304-339.

Meland, Ingmar (2010), 'Rehabilitating Ernst Cassirer and his Philosophy: Four Recent Contributions', *SATS (Northern European Journal of Philosophy),* 11, 235-256.

Mills, M. Anthony (2014), 'Identity versus determinism: Émile Meyerson's neo-Kantian interpretation of the quantum theory', *Studies in History and Philosophy of Modern Physics,* 47, 33-49.

Mormann, Thomas (forthcoming), 'Wissenschaftliche Philosophie im Exil: Cassirer und der Wiener Kreis nach 1933', in: Matthias Neuber (ed.), *Husserl, Cassirer, Schlick: Wissenschaftliche Philosophie im Spannungsfeld Phänomenologie, Neukantianismus und logischem Empirismus* (Springer).

Nagel, Ernest (1938), 'Determinismus und Indeterminismus in der Modernen Physik by Ernst Cassirer', *Philosophy of Science* 5(2), 230-232.

Natorp (1912), 'Kant und die Marburger Schule', *Kant-Studien 17*, 193-221.

Neuber, Matthias (2012), *Die Grenzen des Revisionismus, Schlick, Cassirer und das 'Raumproblem'*, Moritz Schlick Studien, 2 (Wien: Springer).

Padovani, Flavia (2011), 'Relativizing the Relativized A Priori: Reichenbach's Axioms of Coordination Divided', *Synthese*, 181 (1), 41-62.

Patton, Lydia (2005), 'The critical philosophy renewed: The bridge between Hermann Cohen's early work on Kant and later philosophy of science', *Angelaki,* 10 (1), 109-118.

Peetre, Jaak & Magnusson, Rooney (eds.) (2009), *Correspondence of Marcel Riesz with Swedes: Part II*. URL: http://www.maths.lth.se/matematiklu/personal/jaak/Riesz1.pdf (7-10-2014).

Pettersson, Hans (1937), 'Review: Determinismus und Indeterminismus', *Theoria*, 3, 343-345.

Pringe, Hernán (2007), *Critique of the Qauntum Power of Judgment*, Kantstudien-Ergänzungshefte, 154 (De Gruyter).

——— (2014), 'Cassirer and Bohr on Intuitive and Symbolic Knowledge in Quantum Physics', *theoria*, 81, 417-429.

Rickert, Heinrich (1921), *Der Gegenstand der Erkenntnis: Einführung in die Transzendental-Philosophie* (Tübingen: J. C. B. Mohr).

Riezler, Kurt (1928), 'Die Krise der "Wirklichkeit"', *Die Naturwissenschaften*, 16 (37-38), 705-712.

Ryckman, Thomas (1991), 'Conditio sine qua non? Zuordnung in the early epistemologies of Cassirer and Schlick', *Synthese*, 88, 57-95.

——— (2014), ''A believing rationalist': Einstein and 'the truly valuable in Kant', in: Christoph Lehner & Michel Janssen (eds.), *The Cambridge Companion to Einstein* (New York: Cambridge University Press).

Schlick, Moritz (1918), *Allgemeine Erkenntnislehre*, in: F. O. Engler & H. J. Wendel (eds.), *Kritische Gesamtausgabe* (Wien: Springer (2008)).

——— (1921), 'Kritizistische oder empiristische Deutung der neuen Physik? Bemerkungen zu Ernst Cassirers Buch *Zur Einstein'schen Relativitätstheorie*', *Kantstudien*, 26, 96-111. Translated as 'Critical or Empiricist Interpretation of Modern Physics?', in: H. Mulder & B. van de Velde-Schlick (eds.), *Moritz Schlick: Philosophical Papers (1909-22),* (Dordrecht: Reidel (1979)), 322- 334.

Schmitz-Rigal, Christiane (2002), *Die Kunst offenen Wissens: Ernst Cassirers Epistemologie und Deutung der modernen Physik*, Cassirer-Forschungen (Hamburg: Felix Meiner

Verlag).
——— (2009), 'Ernst Cassirer: Open Constitution by Functional A Priori and Symbolical Structuring', in: Michel Bitbol et. al. (eds.), *Constituting Objectivity: Transcendental Perspectives on Modern Physics,* The Western Ontario Series in Philosophy of Science, 74 (Paris: Spinger), 75-94.
Sigurdsson, Skúli (1992), 'Essay Review: Einsteinian Fixations' (review of: Klaus Hentschel's *Interpretationen und Fehlinterpretationen der speziellen under allgemeinen Relativitätstheorie*), *Annals of Science,* 49, 577-583.
——— (2007), 'On the Road', in: K. Gavroglu and Jürgen Renn (eds.), *Positioning the History of Science* (Springer), 149-157.
Stöltzner, Michael (1999), 'Vienna Indeterminism: Mach, Boltzmann, Exner', *Synthese,* 119, 85-111.
——— (2003), 'Vienna Indeterminism II: From Exner's Synthesis to Frank and Mises', in: W. Salmon P. Parrini, M. Merrilee (eds.), *Logical Empiricism: Historical and Contemporary Perspectives* (Pittsburgh University Press), 194-232. URL: http://philsci-archive.pitt.edu/624/ (27-10-2014).
——— (2011), 'The Causality Debates of the Interwar Years and Their Preconditions: Revisiting the Forman Thesis from a Broader Perspective', in: Carson, Kojevnikov, Trischler (eds.), *Weimar Culture and Quantum Mechanics* (Imperial College Press), 505-522.
Van Strien, Marij (2014), 'On the origins and foundations of Laplacian determinism', *Studies in History and Philosophy of Science,* 45 (1), 24-31.
Sundaram, K. (1972), 'Kant or Cassirer: A study in Complementarity', *Zeitschrift für allgemeine Wissenschaftstheorie,* 3 (1), 40-48.
——— (1987), *Cassirer's Conception of Causality* (Peter Lang).
Torretti, Roberto (1999), *The Philosophy of Physics* (The Evolution of Modern Philosophy; Cambridge: University Press).
Weizsäcker, Carl Friedrich von (1937), 'E. Cassirer, Determinismus und Indeterminismus in der modernen Physik. Historische und systematische Studien zum Kausalproblem.', *Physikalische Zeitschrift,* 38, 860-861.
——— (1941a), 'Die Physik der Gegenwart und das physikalische Weltbild', *Die Naturwissenschaften,* 29, 185-194.
——— (1941b), 'Zur Deutung der Quantenmechanik', *Zeitschrift für Physik,* 118 (7-8), 489-509.
Werkmeister, William H. (1966), 'Cassirers Verhältnis zur neukantianischen Philosophie', in: Paul Arthur Schilpp (ed.), *Ernst Cassirer* (Philosophen des 20. Jahrhunderts; Berlin: Kohlhammer Verlag), 532-565.