The Vienna Circle against Quantum Speculations

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Abstract
The theory of quantum mechanics has often been thought to show an affinity with logical empiricism: in both, observation plays a central role, and questions about what is unobservable are dismissed. However, there were also strong tensions between the logical empiricism of the Vienna Circle and certain implications drawn from quantum physics. In the 1920s and 1930s, many physicists thought that quantum mechanics revealed a limit to what could be known scientifically, and this opened the door to a wide range of speculations, in which quantum mechanics was connected with free will, organic life, psychology and religion – speculations in which many leading quantum physicists engaged. Members of the Vienna Circle, such as Frank and Schlick, looked at quantum mechanics for a confirmation of their empiricist views, but were at the same time critical about these wider implications drawn from quantum mechanics, which in their eyes were connected with broader mysticist and irrational trends in society. They engaged in particular with the views of Bohr and Jordan, both of whom expressed affinities with logical empiricism while at the same time arguing for claims which proved hard to reconcile with the scientific world conception of the Vienna Circle.

Introduction

The theory of quantum mechanics was developed around the time when logical empiricism emerged as a movement in philosophy, in the 1920s, and at first sight, there seem to be certain similarities: both in quantum mechanics and in logical empiricism, one speaks only about what can be observed or measured, and questions about what lies beyond observation are rejected as unanswerable or meaningless. It is no surprise that quantum physics was a frequent topic of discussion within the Vienna Circle, the group of Viennese philosophers that formed one of the main cores of logical empiricism: especially in the 1930s, quantum mechanics was regularly discussed in meetings of the Vienna Circle and in lectures and conferences organized by the logical empiricist movement.[1] Members of the Vienna Circle looked at

[1] A list of topics discussed at meetings of the Schlick Circle in the years 1927-1932, together with notes from some of these meetings, show that quantum mechanics was discussed at at least five meetings during this period (Stadler 2001, 73-79). At most of the conferences at which the Vienna Circle had a large presence in 1929-1937, there was at least one lecture by a member of the Vienna Circle on a topic related to quantum mechanics (see the conference programs in Stadler 2001); notably, quantum mechanics was discussed in lectures by Frank, Reichenbach and Zilsel at the

quantum physics for a confirmation of their views, and sought for philosophical allies among quantum physicists.

However, the relation between the Vienna Circle and quantum physics was not altogether unproblematic: quantum mechanics was frequently used to argue for claims that were in direct opposition to what logical empiricism stood for. In particular, in the 1920s and 1930s, one frequently encountered the claim that quantum mechanics had shown that there was a fundamental limit to the scope of science, and quantum mechanics was often connected (not in the least by leading quantum physicists themselves) to speculative ideas about religion, free will, psychology, and organic life (see section 1). These speculative uses of quantum mechanics were hard to reconcile with the logical empiricists' rejection of metaphysics and speculation: many of the philosophical problems that were connected to quantum mechanics, such as the problem of free will, were according to the logical empiricists mere pseudo-problems.

Whereas existing literature on the relations between the logical empiricism and quantum mechanics tends to focus either on the question whether and in what way logical empiricism influenced the development of quantum mechanics or on the question how conceptions of causality were revised in light of quantum mechanics (see e.g. Faye 2010; Ryckman 2007; Stöltzner 2003, 2011), my focus will be on the question of the legitimacy of connecting quantum mechanics with broader philosophical issues. I argue that within the Vienna Circle, discussions about quantum mechanics were not just aimed at gaining a better understanding of foundational issues within quantum mechanics. Rather, especially for Philipp Frank, the central issue was what broader philosophical conclusions could legitimately be drawn from the theory: he was particularly concerned to argue against the idea that quantum mechanics sets a fundamental limit to science, or that it supports any kind of mysticism. Furthermore, there was a strong ideological and even political background to the attempts to clear up the misunderstandings connected to quantum physics.

Members of the Vienna Circle engaged in particular in exchanges with the quantum physicists Pascual Jordan and Niels Bohr, both of whom argued that quantum mechanics could yield new insight into problems in psychology and biology, although the ways in which they argued for this were very different: whereas Bohr argued that quantum mechanics provided insight in our understanding of life and free will through analogy, Jordan thought that quantum mechanics had *direct* implications for life and free will. Section 1 of this paper introduces the main ideas of the Vienna Circle and its relations with quantum mechanics, and in section 2 and 3, the different views of Bohr and Jordan on the significance of quantum mechanics for biology and psychology are presented. Jordan's ideas met with serious criticism from members of the Vienna Circle (section 4); who subsequently tried to reach an agreement with Bohr about an interpretation of quantum mechanics that would not lend itself to misunderstandings and illegitimate conclusions (section 5); however, this attempt to reach a common understanding was only partially successful, and it proved difficult to find an account of quantum mechanics which was fully in accordance with the Vienna Circle's scientific world conception.

Preliminary Conference of the International Congress for the Unity of Science (Prague, 1934), and was discussed extensively at the *Second International Congress for the Unity of Science* (Copenhagen, 1936).

1. The Vienna Circle, quantum mechanics, and their relations

Central to the scientific world conception of the Vienna Circle is the claim that one cannot meaningfully speak about what lies beyond the domain of science. This means that all metaphysics should be rejected, that there is no independent domain of philosophy, and that philosophical problems should either be reformulated as empirical questions or rejected as meaningless. The basis of science, in the Vienna Circle's account, lies exclusively in observations and logic. Another central tenet is the unity of science: ultimately, every sentence should be translatable into a language common to all sciences. More generally, the Vienna Circle stood for the ideals of clarity and enlightenment. This was connected with a social and political engagement: the hope was that the strict demands of empirical evidence and rational arguments would contribute to a rational restructuring of society, and that in this way, society could be defended against irrational tendencies stemming from religion, mysticism and nationalism (Romizi 2012).

The members of the Vienna Circle who wrote most extensively about quantum physics were Moritz Schlick and Philipp Frank. Both were physicists as well as philosophers. Schlick, the informal leader of the Vienna Circle, had obtained a doctorate in physics with Max Planck, after which he switched to philosophy and became well-known for his philosophical writings on Einstein's theory of relativity. Frank studied physics and mathematics in Vienna, and from 1912 held a professorship in physics at the German University of Prague; while in Prague, he kept close connections with Vienna and was an active member of the Vienna Circle. The Vienna Circle was associated with logical empiricist philosophers elsewhere, such as the Berlin Circle around Hans Reichenbach. In the 1930s, logical empiricism gave rise to the unity of science movement, which developed the idea that all sciences share a common basis.

The development of quantum physics started in the first decade of the twentieth century; after some years of development, the theory of quantum mechanics was introduced in the years 1925-26. Many physicists contributed its development: in particular Heisenberg, Born, Jordan, Schrödinger, and Bohr made essential contributions. It is an unusual theory in many ways, and discussions about its interpretation haven't stopped since. The theory does not give a deterministic account of quantum phenomena, but merely yields probabilistic predictions for measurement outcomes; however, this is not yet its most unusual aspect. More radical features include the idea that it is not possible to observe a quantum system without changing it, so that the measurement process itself becomes a central point of interest. Heisenberg's uncertainty principle, introduced by Werner Heisenberg in 1927, states that the position and momentum of a particle cannot simultaneously be known with arbitrary accuracy, which is related to the fact that they cannot simultaneously be measured. Bohr's related notion of complementarity expresses the idea that there are pairs of concepts which cannot be used simultaneously, because they can only be applied in the context of experimental settings which exclude each other: here, position and momentum form one example, since the experimental setting in which the position of a particle can be measured excludes the simultaneous measurement of its momentum. Similarly, there is no point in asking whether light consists of waves or particles: we can only say that light will behave like waves in certain experimental settings, and will behave as if it is constituted by particles in other experimental settings.

The centrality of observations and measurements, and the fact that questions about things which cannot be observed are rejected rather than answered, are central features of quantum mechanics. Erwin Schrödinger saw in these features an affinity with the broader culture at the time. In his lecture titled *"Ist die Naturwissenschaft milieubedingt?",* held in 1932, Schrödinger argues that quantum mechanics only deals with observed facts: "This creates 'empty spaces' in physics, just like on our furniture and walls. We no longer shy away from them, we don't try to fill them up with flourishes, as we sometimes did in the past. We want the image of nature to be such that it says *nothing* about things that are in principle beyond observation" (Schrödinger 1932, 44). Also the Vienna Circle had a notable affinity with modernism in art and architecture (Galison 1990, Dahms 2004). But more direct similarities between the ideas of the Vienna Circle and quantum mechanics can be pointed out: also for the Vienna Circle, observations are central to scientific knowledge, and also for the Vienna Circle, it is not possible to say anything about what is in principle unobservable: questions about what goes beyond the observable should be either reformulated or rejected.

Given the interest of logical empiricists in the exact sciences, it is no surprise that quantum mechanics was frequently discussed in the meetings and conferences in which the Vienna Circle was involved. In the late 1920s and 1930s, there were various interactions between members of the Vienna Circle and quantum physicists.[2] This raises the question of influence. It has often been suggested that logical empiricism may have influenced the development of quantum mechanics, but closer studies show that this was probably not the case: the development of quantum mechanics seems to have been driven by internal and technical concerns, with no large influences from philosophy (Beller 1999; Faye and Jaksland 2021a). Also the role of logical empiricism in the way quantum physicists interpreted the theory of quantum mechanics seems to have been limited, although Faye (2010) argues that Bohr's interactions with logical empiricists may have helped him in formulating his response to the EPR paradox, which was raised by Einstein, Podolsky and Rosen in 1935. Although more can be said about possible influences of logical empiricism on the development of quantum mechanics, it is not the aim of this paper to contribute to this issue.

Rather, I will focus on the reactions to quantum mechanics within the Vienna Circle. I argue that logical empiricists saw in quantum mechanics a confirmation of their views; however, they also saw challenges, in particular in the ways quantum mechanics was connected to questions of organic life and the mind. In the 1920s and 1930s, many physicists saw in quantum mechanics a liberation from the oppressive mechanism, materialism and determinism of the physics of the nineteenth century, and this opened the door to a wide range of speculations: it was not uncommon for physicists to explore connections between quantum mechanics and psychology, free will, religion, and the secrets of organic life. For example, in widely read popular accounts of quantum physics, Eddington and Jeans argued that the development of quantum mechanics disproved materialism, supported idealist views and brought physics closer to religion (Stanley 2007; Tuboly 2020). As we will see, both Bohr and Jordan argued (in very different ways) that quantum mechanics could yield insights into the fundamental problems of consciousness and organic life. Also Pauli thought that quantum

[2] Besides the interactions described in this paper, Heisenberg engaged in discussion with members of the Vienna Circle at the Second Conference on the Epistemology of the Exact Sciences in Königsberg, 1930.

physics had a significance for psychology: in 1932 he started an extensive correspondence with Carl Gustav Jung, among others discussing the relations between physics and psychology (Gieser 2005). There was often a sense of quantum mechanics being deeply relevant for philosophical issues and being somehow mysterious, even though physicists' use of terms like 'mysticism' in connection with quantum mechanics should not always be taken at face value (Seth 2008).

The tendency to connect quantum physics with big questions and speculative ideas was hard to reconcile with a restriction to what is observable, and directly opposed to the sober world view of the Vienna Circle. Tensions between logical empiricists and quantum physicists soon emerged. The Vienna Circle first presented itself publicly in 1929, at the First Conference on the Epistemology of the Exact Sciences, held in Prague in connection with the 5th Meeting of German Physicists and Mathematicians. At this occasion, a manifesto of the Vienna Circle was presented, and the Meeting of German Physicists and Mathematicians started with an opening lecture by Philipp Frank, in which he gave an outline of the viewpoints of the Vienna Circle (Frank 1930). Also the second lecture on the program, by Richard von Mises, supported a logical empiricist viewpoint; however, the third lecture, by the quantum physicist Arnold Sommerfeld, contained a strong criticism of the program and of empiricism in general (Sommerfeld 1929; Stöltzner 2020).

Criticizing the empiricist views of Frank and Von Mises, Sommerfeld argued for a realist account of science in the style of Max Planck.[3] Furthermore, he argued that quantum mechanics exhibits a type of final causation: in certain situations, what happens at a certain moment is determined not only by the initial but also by the final state of the system. The term 'finality', which Sommerfeld uses, may be associated with teleology or purposiveness, which is often thought to be characteristic of organic life. Although Sommerfeld rejected the idea that the finality exhibited in quantum mechanics should be understood in terms of purposes, he nevertheless argued that it formed a type of causality which was better suited to biology than the causality of classical physics (Sommerferld 1929, 868). Sommerfeld furthermore suggested that quantum mechanics may be relevant for understanding the relation between body and soul (Sommerfeld 1929, 870; Stöltzner 2020).

Further encounters between logical empiricism and quantum mechanics took place in particular in connection with the preliminary conference of the unity of science movement in Prague in 1934, where logical empiricists expressed harsh criticism of the quantum speculations of Pascual Jordan (section 4), and at the Second International Congress for the Unity of Science in Copenhagen in 1936, where Frank and Schlick attempted to find a common understanding with Niels Bohr (section 5). Bohr and Jordan both applied the ideas of quantum mechanics to the domain of biology and psychology; to understand the engagement of members of the Vienna Circle with the views of Bohr and Jordan, we first need to say more about these views themselves.

[3] In earlier years Schlick's position had been one of critical realism, possibly influenced by the realism of his PhD advisor Planck; however, by 1931, Schlick was critical of Planck's realism (Neuber 2016).

2. Bohr on the significance of quantum mechanics for biology and psychology

Bohr first introduced his notion of complementarity in 1927, at an international congress in Como, Italy, in order to make sense of some features of quantum theory. This notion expresses the idea that there can be pairs of concepts or attributes which cannot be applied at the same time, even though both are needed to describe a certain system. Bohr argued for example for a complementarity between the descriptions of light as consisting of waves or of particles. This complementarity is explained by the idea that certain concepts or descriptions can only be applied relative to a certain experimental setting, and that experimental settings can be mutually exclusive: for example, the position and momentum of a particle cannot both be measured at the same time, because they require different experimental setups which cannot be combined. If a quantum system can only be described through attributes which stand in complementary relations with each other, this entails that we can not describe the system as it is in itself: we have no set of concepts with which we can give a full description of the system at all times. Rather, we can only say how it will behave under specific experimental conditions. According to Bohr, this is a consequence of the fact that in quantum mechanics, observed phenomena can never be taken to be independent of the experimental arrangement with which they are observed: there is always an interaction between the object and the measurement instrument. (On Bohr's notion of complementarity, see e.g. Faye 1991, Folse 1985, Held 1994).

Bohr's notion of complementarity thus enables the use of apparently conflicting conceptions, while avoiding direct contradictions. It is essential to Bohr's thought on this topic that this complementarity cannot be overcome by developing new concepts: for example, we cannot replace the concepts of 'position' and 'momentum' by new concepts which can be applied simultaneously, in order to give a more accurate description of the movements of an electron. Bohr argues that we have to hold on to what he calls classical concepts, like position and momentum, because these concepts are needed for unambiguous communication. This means that we have to content ourselves with a set of concepts of which the applicability is restricted.

Heilbron (1985) has characterized Bohr's views on quantum mechanics as a "combination of resignation and enthusiasm". Bohr's enthusiasm about the notion of complementarity can be seen from his efforts to apply this notion also in other contexts, notably in biology and psychology. He argued that in psychology, we encounter a situation which is similar to that in quantum physics, in the sense that it is not possible to observe our own psychological state without changing it: when we pay conscious attention to our own thoughts, this changes our course of thought (Bohr 1932). This situation similarly gives rise to complementarities, such as a complementary relation between having emotions and analyzing them. Bohr also suggests the idea of a complementary relation between causality and free will: although the conceptions of causality and of free will are in apparent conflict with each other, we need both (Bohr 1929/1931).

Also in biology we encounter a similar situation, according to Bohr. In 1932, Bohr held a lecture at a conference on light therapy, titled 'Light and Life', in which he argued that if we approach an organism with the methods of physics and chemistry, and we want a full understanding of the workings of the organism, this requires very invasive examinations, to such a degree that the organism cannot remain alive. Alternatively, an organism can be approached as essentially alive, using conceptions which are specific to biology. Bohr suggests that these two approaches can stand next to each other without causing direct contradictions, because of the fact that the experimental conditions under which an organism is studied as a physico-chemical system and the conditions under which it is approached as a living system exclude each other: "... the conditions holding for biological and physical researches are not directly comparable, since the necessity of keeping the object of investigation alive imposes a restriction on the former, which finds no counterpart in the latter. Thus, we should doubtless kill an animal if we tried to carry the investigation of its organs so far that we could describe the role played by single atoms in vital functions" (Bohr 1933, 458).

This application of the notion of complementarity to biology implies that physics alone can never suffice to give a full account of organic life. According to Bohr, we encounter in biology a constraint on the scope of physics. The methods of physics and chemistry can be used to get a better understanding of the workings of an organism, but ultimately, life remains unexplainable by physico-chemical means, and for Bohr this seems to mean that life remains unexplainable, period: "In every experiment on living organisms, there must remain an uncertainty as regards the physical conditions to which they are subjected, and the idea suggests itself that the minimal freedom we must allow the organism in this respect is just large enough to permit it, so to say, to hide its ultimate secrets from us" (Bohr 1933, 458). Thus, we have to count with the possibility that "The very problem of the distinction between the living and the dead escapes comprehension in the ordinary sense of the word" (Bohr 1929/1931, 77). Bohr argues that the concept of life, like the quantum of action, is not further analyzable and must ultimately be accepted as given.

Hoyningen-Huene (1993) has given an analysis of Bohr's argument for complementarity in biology, and convincingly argues that the argument *presupposes* the irreducibility of biology to physics, rather than deriving it. Bohr's starting point is the idea that the purposiveness we attribute to organisms is not compatible with physics, but that we are not warranted either to assume that it is due to a vital force which is at play in organisms. His concept of complementarity then explains how biology can be irreducible to physics without coming into conflict with the laws of physics, and how the assumption that organisms are composed of physical entities can be combined with the attribution of teleology to organisms, while avoiding direct contradiction.

It has been argued that there are Kantian elements in Bohr's conception of complementarity: Kant argued in his antinomies that our conceptions can lead to opposite conclusions, and also argued that both the mechanistic and the teleological conception play a role in biology, despite being incompatible with each other (on the relation between Kant and Bohr, see e.g. Faye 1991, 103-4; Cuffaro 2010). A significant philosophical influence on Bohr was the Danish philosopher Harald Høffding, who was a close friend of the Bohr family (Faye 1991). Moreover, also Bohr's father Christian Bohr seems to have played a role in the development of Niels Bohr's thoughts: Christian Bohr was a physiologist, who reportedly thought that both the unrestricted use of the methods of physics and chemistry and a teleological point of view are indispensable within physiology. Niels Bohr believed that his notion of complementarity could show how these seemingly opposed views can coexist (Holton 1970, 179-81; Faye 1991, 157).

Although according to Bohr, the notion of complementarity could have a deep significance for biology and psychology (among others), it is important to note that the argument is essentially an argument from analogy. Although Bohr remarked that quantum effects may play a role in organisms, his argument for the role of complementarity in biology does not rely on this: rather, the argument is that in biology, we encounter a situation which is in some ways similar to the situation encountered in quantum physics, and that the notion of complementarity can help to explain this situation. Quantum mechanics has thus given us an epistemological conception which can be helpful in other scientific disciplines as well.

3. Jordan on the significance of quantum mechanics for biology and psychology

Bohr's interest in the relevance of quantum mechanics for psychology and biology was shared by Pascual Jordan. Jordan talked extensively with Bohr about life and free will, and presented his ideas on this topic as a continuation of those of Bohr (see Beyler 1994, 103; Sloan 2011, 65). However, Jordan took Bohr's ideas several steps further: in particular, he argued not only for an analogy, but for a direct relevance of quantum mechanics for organic life.

To account for the special features of organic life as well as for free will, Jordan proposed what he called the 'amplifier theory' (*Verstärkertheorie*). The basic idea is that quantum effects play a role in certain key processes within organisms: "Precisely those organic reactions through which, according to the results of physiology, the roughly macroscopic reactions in the body of animals and humans are directed (e.g. the finest light perceptions; furthermore probably reactions in the nucleus of cells, e.g. during procreation processes) are, according to the results of physiology, often of a delicacy reaching down to the atomic level, and are therefore no longer subject to deterministic causality" (Jordan 1932, 819).

The idea is that within the organism, quantum effects can be magnified to make a difference for the organism as a whole.[4] This can happen especially in processes within the brain, genetic processes, and through light perception. This means that organisms are not fully subjected to mechanistic causality, but on the contrary exhibit the same acausality as quantum objects: Jordan suggests that for this reason, it would make sense to think of organisms as microphysical systems (Jordan 1934; on Jordan's quantum biology see e.g. Beyler 1994, 1996; Roll-Hansen 2011; Sloan 2011). The claim that individual quantum events could make a difference for the organism as a whole found some experimental support in the finding that genetic mutations could be brought about by radiation (Jordan 1934; Sloan 2011).

According to Jordan, the fact that quantum acausality plays a role in organisms opens up possibilities to account for the special features of organic life. But this is not a task for

[4] Although Jordan's acount of free will and organic life takes the indeterminism of quantum mechanics as a starting point, similar views were already formulated before the introduction of quantum mechanics. Around the 1870s, a number of physicists speculated that organisms may be highly sensitive systems, so that an immaterial 'directive principle' may be able to trigger motions in an organism by exerting a force which can be infinitely small or even zero (Van Strien, 2014). The idea that micro-physical indetermination is amplified in organisms can also be found in the work of Henri Bergson, in connection with more subtle ideas about the relation between body and mind (see Čapek 1971).

physics: rather, Jordan argues that the fact that organisms are not fully subjected to deterministic causality creates space for biologists to account for organic life in non-mechanical terms, and to attribute holistic and teleological features to organisms (Jordan 1934). Jordan also suggests that whereas in atomic physics, the limit of accuracy of observations is given by the Heisenberg uncertainty relations, certain parts of the organism may be more sensitive to disturbance and therefore only admit less accurate observation: for example, chromosomes may be characterized by an "even higher degree of unobservability of their physical states than we know from atomic physics" (Jordan 1932, 820). This would create even more space to argue for holistic features of organic life.

Jordan thought that his amplifier theory could also account for the possibility of free will, which he thought should be accepted as a primitive fact: "...in our inner experience we sense the process of free decision as a means of choosing the most appropriate among various possible modes of reaction. We have to get used to considering such primitive but fundamental facts of experience to be more meaningful than the prejudices that stem from outdated doctrines" (Jordan 1934a, 243).

The fact that Jordan speaks of organisms being 'steered' or 'directed' by quantum processes, and that this is directly connected to the idea that the behavior of the organism is somehow coordinated, as well as to free will, suggests a dualist interactionism: it suggests the idea that quantum mechanics creates space for a non-material entity, such as a soul, a vital force or an entelechy, to act without violating any laws of physics. However, Jordan does not explicitly make this step, and it remains unclear what exactly does the steering.

Building on Bohr's ideas on complementarity, Jordan carried the idea that the acausality of quantum mechanics is essential to organic life still further. He argues that in quantum mechanics, it is not possible to observe a system without interacting with it and changing it, and that in fact, quantum objects only take on definite properties through observation: before the position of an electron is measured, it is indeterminate (Jordan 1932). This means that quantum indeterminacy is suppressed through observation. When a person is subjected to close examination to determine the exact physical state of the body, this will suppress quantum indeterminacy in the body, as gradually the feeling of free will is suppressed and, if the examination is carried far enough, the person dies. This suggests, according to Jordan, that quantum indeterminacy is essential to life, and that there is a very literal complementarity between the organism being in a definite physical state and it being alive: "The transformation of a state of liveliness into a state of greatest possible definiteness means a radical *killing*" (Jordan 1932, 821).[5]

Jordan furthermore connects the concept of indeterminacy within quantum mechanics with the unconscious in psychoanalysis: the unconscious may be indeterminate in a quantum mechanical sense, which would mean that only once a certain thought or memory is made conscious, it takes on a definite form. Jordan writes that this effect is behind the efficacy of psychoanalytic treatment, in which unconscious thoughts or memories are transformed by bringing them into the conscious mind (Jordan 1934). He draws further connections with parapsychology, specifically telepathy and clairvoyance, as well as with Lamarckist evolution

[5] He notes furthermore that it is no coincidence that X-rays, which are quantum mechanical in nature, make it possible to observe the inner state of an organism but are at the same time harmful to the organism (Jordan 1932, 819).

(Wise 1994). At this point, it is clear that his ideas on the significance of quantum mechanics for biology and psychology get quite wild.

The interesting point, however, is that at the same time, Jordan presented himself as a positivist. Few physicists at the time drew connections between quantum mechanics and logical empiricism, but Jordan explicitly argued that quantum mechanics should be understood positivistically and confirmed logical empiricist views. In particular, he argued that quantum mechanics is solidly based on observable phenomena, and that one of the fundamental ideas at the basis of quantum mechanics is the idea that questions about what is in principle unobservable should be put aside as pseudo-problems. In 1934, Jordan published an article in *Die Naturwissenschaften* on the relations between positivism and modern physics: he characterizes positivism through a concern with distinguishing between meaningful and meaningless statements and through the demonstration that many philosophical problems are in fact pseudoproblems, and offers refutations of common objections to positivist philosophy, arguing e.g that positivism does not rely on the claim that there are primitive elements of experience which are not further analysable, and that positivism does not entail the claim that there is no external world (rather, the question of the existence of an external world is declared meaningless) (Jordan 1934b). However, as Beyler (1994, 50) convincingly argues, Jordan's positivism was more naive than that of the Vienna Circle, and could take the form of uncritically accepting what is given in experience. As we have seen, Jordan accepted the freedom of the will as a primitive fact which is given in experience, whereas members of the Vienna Circle tended to give a more critical analysis of the concept of free will, and to argue that the problem of free will is a pseudo-problem.[6]

What appealed to Jordan in positivist philosophy was the fact that it did not hold on to doctrines of causal necessity or materialism. For Jordan, materialism was associated with atheism and Marxism, both of which he strongly opposed (Beyler 1994). Logical empiricists commonly argued that both materialism and idealism were illegitimate metaphysical positions. Moreover, logical empiricists argued that the idea that nature is subjected to necessary causal relations can be given no clear sense: we can merely ask what regularities hold between the phenomena, and this is a purely empirical question. In Jordan's view, this created space to think about alternatives to strict mechanical causality and materialist reductionism – but his speculations about biology and psychology are hard to reconcile with his professed positivism.

Besides his attempt to affiliate himself with positivism, Jordan also tried to connect to the movement of organicism. Organicists, such as Karl Ludwig von Bertalanffy and Adolf Meyer-Abich, argued that the organism should be considered as a whole, rather than investigated with analytic, reductionist methods: an organism cannot be understood as merely the sum of its parts (Beyler 1996). Both Bertalanffy and Meyer-Abich expressed support for Jordan's ideas on the relevance of quantum physics for biology, although Bertalanffy had some reservations: Jordan's amplifier theory entailed that the behavior of the organism as a whole is centrally directed by certain parts of the organism, which did not fit very well with the antireductionistic holism which was central to organicism (Beyler 1994).

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[6] On Jordan's relation to logical empiricism, see also Howard (2013).

Another aspect of Jordan's thought were his political views – specifically, his commitment to national socialism. Jordan became a party member in 1933, and published various essays about politics, first under pseudonym (1930-32) and later under his own name. In these essays, he presented conservative, nationalistic and authoritarian views, expressed criticism of democracy, and emphasized the importance of physics for military interests (Beyler 1994; see also Hoffmann and Walker 2020). Jordan's ideas on biology and psychology cannot be seen as fully independent of his political views. Wise (1994) has argued that Jordan used many terms and expressions with a Nazi connotation: in particular, Jordan's amplifier theory is based on the idea of central coordination of the operations of the organism, in which a small group of molecules has a "dictatorial authority" over the organism. According to Wise, "Jordan's picture of the world, from beginning to end, from physics to philosophy to politics, centred on the necessity for leadership through power in the organization of complex systems and on a willingness to manipulate other people and their ideas in the greater interest of justifying power" (Wise 1994, 253-54).

Moreover, Jordan's views on organic life fit within a more general trend of holism and organicism in Germany in the 1930s, which was often associated with national socialist ideology (Harrington 1996). It was common to compare the nation (*Volk)* to an organism, which implied the holistic idea that the nation is more than the sum of the individuals who compose it, and that individuals should act in the greater interest of their nation. As Harrington (1996, 208) stresses, it is certainly not the case that everyone who was sympathetic to holistic views of organic life in this period was also sympathetic to national socialism; and conversely, it is not the case that all Nazis were sympathetic to holism. There were in fact strong tensions and oppositions within national socialism, especially between reactionary and modernist views (Beyler 1994; 1996). Whereas holism and organicism fit with the more reactionary ideological tendencies, the more modernist strands of national socialism emphasized scientific progress, technological innovation, efficiency and mechanism, and in this context holism could be seen as a religious doctrine standing in the way of scientific progress (Beyler 1996). The modernist aspects of national socialism became more important from the late 1930s onwards, under the pressure of war, and these aspects now dominate the image of national socialism: efficient, mechanized killing, the cold rationality of the bureaucrats (Harrington 1996, 198-211). But during the 1930s, associations between holism, organicism and national socialism did exist, and these associations loomed in the background of discussions about holist versus mechanist views of organic life. For this reason, as we will see in section 4, also the reactions to Jordan's views on organic life cannot be seen independently of politics.

Like there were tensions between different approaches to organic life within national socialist ideology, there were also tensions between different approaches to physics. The 'Deutsche Physik' movement was critical of the modern theories of relativity and quantum mechanics, and connected the overly abstract and mathematical nature of these theories to the fact that they were largely developed by Jewish physicists. 'Deutsche Physik', in contrast, emphasized mechanism, 'Anschaulichkeit' (picturability or intuitivity) and common sense.[7]

[7] The emphasize on mechanism within physics could go together with holistic organicism. Frank noted that those who argued for organicism in biology also often argued for mechanism and *Anschaulichkeit*

Jordan, who despite his sympathies with national socialism does not seem to have expressed anti-Semitic views, defended modern physics against the criticisms of 'Deutsche Physiker'. He argued against the idea of cultivating a national style in physics: although there may indeed be certain differences in style between scientific traditions in different countries, these differences will turn out to be irrelevant when it really matters, namely during war. With the possibility of war on the horizon, German physicists should explore all elements of modern physics which might be useful for military purposes, rather than rejecting part of them for ideological reasons.[8]

Because of his defense of modern physics, Jordan encountered criticism by other Nazi physicists. However, he was not the only one for whom quantum mechanics fit within a national socialist ideology: another example is the popular science writer and school teacher Bernhard Bavink, who argued that quantum mechanics refutes materialism, can contribute to a better understanding of life and the soul, and fits within a religious world view; moreover, Bavink argued that the implications of quantum mechanics were in harmony with national socialism (Bavink 1933, 14; Beyler 1994; Hentschel 1993). Bavink praised Jordan's ideas on the implications of quantum mechanics for biology and psychology, and presented them to a popular audience. Only Jordan's positivism was not acceptable to Bavink.

Jordan thus tried to associate himself with various groups and movements, which had different perspectives on modern science and were on different ends on the political spectrum. He presented himself as a philosophical ally of the (left-leaning) Vienna Circle, but he was not an ally they could easily accept.

4. Jordan and the Vienna Circle

Jordan's attempt to associate himself with logical empiricism had some success: the second major publication in which he presented his views on the significance of quantum mechanics for biology and psychology appeared in 1934 in *Erkenntnis*, the journal of the logical empiricist movement, edited by Rudolf Carnap and Hans Reichenbach. For Jordan himself, the fact that he was able to publish in this particular journal had a special significance: "It is a particular pleasure for me to have the opportunity to express myself in this article *in this specific journal,* which regards the further development of the epistemological conceptions

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in physics: "The reason for the glorification of 'mechanistic' physics by the advocates of organicism is that for their arguments they need the application of a kind of physics that is as narrow as possible and therefore most unsuited for the more involved events." (Frank 1937, 60)

[8] Jordan argues that during war, scientific theories, and the technologies based on them, find their ultimate confrontation, and then it becomes clear that "[t]he differences between German and French mathematics are not more essential than the differences between German and French machine guns" (Jordan 1935b). Wise (1994) calls this the "machine gun principle" of scientific objectivity (see also Beyler, 1994). Jordan's defense of scientific objectivity may seem ironic, since his own writings on the implications on quantum physics were certainly not free of ideology; but for Jordan, what matters is that ideology does not affect scientific theories themselves, and his ideas on the wider implications of quantum mechanics did not call into question the validity of quantum mechanics itself, in contrast to the views of the 'Deutsche Physik' movement.

developed by Ernst Mach as its most important task, and in which I am, as it were, treading on homeland soil, since also for me, the epistemological teachings of Ernst Mach form the basis of all scientific thinking" (Jordan 1934a, 217). By associating himself with Ernst Mach, Jordan placed himself in the empiricist tradition.

We can ask how it came about that *Erkenntnis* offered space for speculative ideas about life and the will, written by an author who, although proclaiming himself to be an empiricist, was so clearly at odds with the logical empiricist movement. Jordan's article was directly preceded by an article by the physiologist Paul M. Jensen, who criticized Jordan's views and argued that there was no reason to abandon determinism in either physiology or physics (Jensen 1934). It may have been Reichenbach who invited Jordan to write a response.[9]

That Jordan's views were less than welcome in this circle, however, became clear at the preliminary conference of the unity of science movement, which took place in Prague that year. Here, Edgar Zilsel presented a strong criticism of Jordan's application of quantum mechanics to biology. Furthermore, Frank gave a lecture arguing against the idea that modern physics (in particular relativity theory and quantum mechanics) supported 'spiritualistic' views. Although Frank does not give a definition of 'spiritualism', he seems to understands it as an affirmation of the existence of a mind, soul, or immaterial organic principle which is irreducible to mechanism. Frank specifically objects to the idea that such a 'spiritualism' can be argued for on the basis of science: he argues against the idea that relativity theory and quantum mechanics provide a basis for a conception of nature "in which the mind again plays a role and which is in good agreement with an 'antimechanistic, organicist, independent' biology" (Frank 1935a, 67). In Frank's (perhaps idiosyncratic) sense, also Jordan's views would classify as spiritualistic. However, Frank does not mention Jordan in this lecture; rather, his explicit targets are the popular science writers Bavink, Eddington and Jeans, as well as the South African statesman General J. C. Smuts, who in 1926 had coined the term 'holism', and who in 1931 had given a presidential address to the British Association for the Advancement of Science, in which he argued that quantum mechanics gave support to an antireductionistic, organicist and holistic conception of organic life (Smuts 1931; Harrington 1996, 269).

Afterwards, the lectures were published in *Erkenntnis,* where Zilsel's contribution was followed by further comments on Jordan's ideas, written by Schlick, Frank, Reichenbach and Otto Neurath. The idea was that these short contributions were "Newly created elements of an 'ideal discussion', which roughly transfer the atmosphere of Prague to the reader".[10] If these texts represent the atmosphere at the conference in Prague accurately, it was an atmosphere which was decidedly hostile to Jordan's proposals: Schlick, Frank and Neurath added to Zilsel's harsh criticisms, and only Reichenbach came to Jordan's defense.

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[9] In correspondence with his co-editor Carnap, Reichenbach wrote, earlier that year: "Ferner habe ich einen Beitrag von dem Physiologen Jensen in Göttingen über Kausalität erhalten. Jordan, Rostock, wird eine Erwiderung darauf schreiben." (Reichenbach to Carnap, 8. March 1934, HR 013-41-28, ASP; also in Carnap forthcoming).

[10] Neurath to Carnap, 26 Oct 1934, RC 029-10-18, Archives of Scientific Philosophy, Pittsburgh; also in Carnap (forthcoming).

The main objection which Jordan's amplifier theory encountered in Prague was that in the end, it merely presents a negation of mechanism and determinism in the organic domain, and adds nothing which would help to explain biological phenomena or establish the autonomy of biology. Schlick argued that it is not completely unthinkable that acausal quantum effects are magnified in organisms, but in the end this would merely introduce an element of chance, and mere chance cannot account for free will or the autonomy of biology (Schlick 1935b). Also Frank argued that Jordan's theory did nothing to establish the autonomy of biology (Frank 1935c). As Zilsel put it: "In the success of quantum mechanics one can only see a confirmation of vitalistic conceptions if one regards a game of dice as being particularly life-like and purposeful" (Zilsel 1935, 57). Jordan's amplifier theory depended on the idea that there can be strong sensitivity or instability in organisms, through which a single event at the quantum scale can make a difference for the organism as a whole; however, Zilsel argued that it is not instability but on the contrary *stability* which is essential for organic life (Zilsel 1935).[11] As the biologist Erwin Bünning argued, in yet another criticism of Jordan published in *Erkenntnis* that year, if acausal quantum events play a decisive role in organisms, this can only be disadvantageous for the organism: "In the organism, an acausal fluctuation that is carried over into the macroscopic realm should as least normally lead to illness or death" (Bünning 1935, 339).

Jordan himself in fact admitted that his theory merely showed the limits of mechanism and determinism, and that the idea that within organisms, quantum effects are magnified, by itself does not account for life. Such amplification also takes place in for example Geiger counters, which are designed in such a way that individual quantum events create an effect on a macroscopic scale, but which are nevertheless not alive. There must thus be an extra feature at play in organisms, which is absent in Geiger counters. In particular, within the organism, instability and acausality must somehow create space for holistic and teleological features of the organism (Jordan 1932). However, Jordan was not able to say how this could work, and his idea that the workings of the organism are 'directed' through quantum events remained obscure.

The idea that organic life was characterized by holistic and teleological features was generally regarded critically by logical empiricists: in particular Frank and Schlick gave critical analyses of the meaning of the concepts of holism and teleology. The core idea of holism was usually formulated as 'the whole is more than the sum of its parts', but both Frank and Schlick argued that this statement could be given no clear meaning, thus suggesting that 'holism' is empty. Schlick argued that in order to interpret the statement 'the whole is more than the sum of its parts', we would first have to define what exactly we mean by 'whole', 'sum' and 'parts': how exactly are the parts added together, and how can we decide whether their sum differs from a whole? According to Schlick, these concepts cannot be defined in a non-arbitrary way, and therefore, whether we use the concept of 'whole' or rather that of 'sum' is merely a matter of convenience (Schlick 1935a). Also Frank argued that there is no criterion which would enable us to distinguish a whole from the mere sum of its parts (Frank 1932/1988, 159-161).

[11] In fact, whereas Jordan's application of quantum mechanics to the domain of biology depended on the idea that organisms can exhibit a strong instability, Schrödinger would later use quantum mechanics to account for the remarkable stability and order of organisms (Schrödinger 1944).

Schlick and Frank also both argued that a clarification of the concept of teleology (or finality) shows that it has nothing to do with purpose. Teleology can be defined as the statement that what happens at a certain moment depends on a future state, which may be interpreted as striving to a purpose; but both Schlick and Frank argued that within physics, when two events depend on each other, one can just as well say that the earlier event depends on the later event as vice versa, thus the distinction between efficient and teleological causation is merely conventional (Schlick 1925; Frank 1932/1988).[12] Frank argued that also in biology, the same situation can be formulated in either teleological terms or in non-teleological terms, and the difference is merely conventional; therefore, "Through the positivistic purification of the concept of finality, it looses everything that makes it so appealing to many natural scientists and philosophers" (Frank 1932/1988, 122, 148).[13]

Frank's and Schlick's criticism of holism and teleology was primarily aimed at German-speaking biologists and philosophers who argued for holistic and organicists conceptions of organic life, such as Bertalanffy and Hans Driesch; Frank also targets Sommerfeld's claim that quantum mechanics exhibits teleology, as well as the holistic views on life and society of the Austrian economist, philosopher and fascist Othmar Spann (Frank 1932/1988, 84, 162-64). Their criticism of holism and teleology implied that these concepts could either be defined in a deflationary way or not be given a definition at all; they could therefore not be used to draw a distinction between the living and the non-living. This undercut Jordan's idea that quantum indeterminacy could create space for holistic and teleological features of the organism and could thereby account for the special features of organic life.

Whereas Jordan's ideas generally met with harsh criticism at the meeting in Prague, Reichenbach came to Jordan's defense, and argued that Jordan's ideas should not be understood as metaphysical speculations but were rather based on empirical hypotheses, in particular the idea that quantum effects are magnified in organisms: although this idea would require empirical support, it should at least be admitted as a possibility and should not be dogmatically rejected (Reichenbach 1935). Also Jordan stressed in his response to the criticisms that his ideas were not metaphysical (Jordan 1935a). The criticism that Jordan's ideas were metaphysical speculations had indeed been made: in particular Neurath had argued that Jordan connected "good, new physics with outdated metaphysics" (Neurath 1935, 181). However, this had actually not been the main criticism to Jordan's ideas: the main criticism was rather that Jordan's account did not enable a better understanding of life or free will.[14]

[12] Schlick and Frank both argue that there is no temporal asymmetry in relations of causation or determination: within physics, the present is determined by the future in the same sense as the future is determined by the present.

[13] In a response to the criticisms his theory encountered, Jordan argued that teleology could be given an exact mathematical formulation through integro-differential equations (Jordan 1935a); however, in the views of Schlick and Frank, this was merely a different way to formulate functional dependencies and could not support the idea of an essential difference between the living and the non-living.

[14] Zilsel labeled Jordan's approach to organic life as 'vitalistic' (Zilsel 1935). As Chen (2019) has recently argued, although logical empiricists were generally critical of vitalism, they did not outright reject vitalism because it went against materialism or was inherently metaphysical; rather, they argued

Although it is unlikely that Jordan's ideas on biology and psychology would have appealed to logical empiricist philosophers in any circumstances, they were probably extra forcefully denounced because they were felt to be connected with dangerous ideological tendencies. Ernest Nagel, who took part in Eight International Congress of Philosophy in Prague (which took place in connection with the meeting where Jordan's views were criticized), reported that the issue of the limits of science was a central topic, and that the atmosphere at the congress was tense, as the rise of national socialism loomed: "More than any previous Congress the one just concluded was characterized by an atmosphere vibrating with the notes of national and social conflict. What was surprising to me was that even in the sections devoted to "pure" philosophy, the same tension was to be found" (Nagel 1934, 589).

Both Zilsel and Frank argued in Prague that the tendency to use quantum mechanics in order to argue for the irreducibility of life or the mind should be explained through the social and political climate at the time. Zilsel noted, in his criticism of Jordan: "Evidently there are today very effective emotional, historical and social circumstances that make vitalism appear appealing and the physical conception of life unappealing" (Zilsel 1935, 183). Frank had argued in (1932/1988) that, whenever a new theory of physics emerges, it tends to be used to argue for a role for subjective and mental factors in science and to be connected to teleology and mysticism. In the past, Frank writes, this had happened for example with Newton's theory of gravity and with electromagnetism, and now the same was happening with Einstein's theory of relativity and with quantum mechanics: "It almost gives the impression that any temporary clouding of the clear structure of physical science results in the triumphant discovery of 'irrational', 'spiritual', or in short mystical moments in physics. The possibility of such discoveries, it seems to me, can be explained with the help of the simple German proverb 'Fishing is good in muddy waters'" (Frank 1932/1988, 230). Frank argues that a further development and clarification of the new theory always brings an end to these interpretations: "From all of this, we see that it is not quantum mechanics through which irrational moments are introduced in physics; rather, the animistic tendencies, which have always been present and lurking for confirmation, use any revolution in physics to assert themselves again" (Frank 1932/1988, 237).

In his lecture in Prague in 1934, however, Frank connects the current misinterpretations of quantum mechanics specifically with the social and cultural climate at the time. Frank argues that the high point of the mechanical world view had come with Laplace and within the cultural context of the French enlightenment. He notes that recently, there has been a turn away from the mechanical world view and towards a more 'organic' natural philosophy, and argues that this development is connected with criticism of the enlightenment and with reactionary philosophy and politics, especially in Italy and Germany – thereby making an implicit connection with fascism. Frank here refers to the holistic and organicist movements among (primarily German-speaking) scientists and philosophers, which, as mentioned in section 3, were frequently associated with national socialism

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that in order for vitalism to be a serious option, one should be able to state laws of life, from which one can derive empirical consequences. According to Chen, the criticism of logical empiricism was essentially that, although the possibility of such a scientific vitalism should be admitted, no successful proposals had been made. This analysis fits with the views of Frank and Schlick, although their deflationary accounts of holism and teleology left little space for such a scientific vitalism.

(Harrington 1996); as an example, he mentions Bavink. Frank argues that this change in world view should be explained through social context: “If expressions with a spiritualistic connotations are again used more today than in the nineteenth century, this has nothing to do with a ‘crisis in physics’ or with a ‘new physical worldview’, but only with a completely differently based crisis in the coexistence of people” (Frank 1935a, 79).

Some years later, Frank argued that a logical empiricist training could teach students to critically analyze the ways in which developments in science are used to argue for religious and political ideologies, and to understand for example “why twentieth-century Fascism has gladly interpreted the ‘crisis of physics’ as a return to organismic physics which could provide a ‘scientific’ support for a return to some political ideas of feudalism” (Frank 1949, 282; and see Tuboly 2020).

The fact that Jordan used quantum mechanics to argue for an organicist world view which fit within a Nazi ideology was pernicious not only because Jordan was one of the leading quantum physicists of the time, but especially because he was one of the few physicists who explicitly associated themselves with logical empiricism. Frank recognized Jordan as a main proponent of positivism in physics (Frank 1935b), despite the fact that Jordan’s applications of quantum mechanics to biology and psychology were exactly the kinds of ideological misinterpretations of modern physics he thought a logical empiricist approach should unmask.

According to Frank, the misinterpretations of quantum mechanics were thus due to irrational tendencies within society, which in the 1930s were on the rise. There is a marked contrast with the controversial analysis of Paul Forman, who has argued for a role of social and cultural factors in the development of quantum mechanics itself: according to Forman, the introduction of acausality in quantum mechanics should be understood as a reaction to an intellectual environment which was hostile to physics in general, and to causality and mechanism specifically (Forman 1971; and see e.g. Stöltzner 2011). Forman specifically points to the role of *Lebensphilosophie,* a philosophical movement which regarded direct experience as superior to scientific knowledge and which has often been linked to irrationalist tendencies in Germany in the 1920s and 1930s, in the development of quantum mechanics, especially through Oswald Spengler’s widely-read *The Decline of the West* (1918).[15] Forman argues that quantum physicists ‘capitulated’ to their intellectual environment by developing an acausal theory of quantum mechanics (Forman 1971). According to Frank, in contrast, it was not quantum mechanics itself, but the way it was used to argue for certain conceptions of life and the mind, which was a product of the current climate: “Where there is thus today a greater tendency to spiritualistic interpretations, this is only connected to processes that have nothing at all to do with the advances made in physics” (Frank 1935a, 69). Thus, whereas Forman thinks that irrationalism is inherent in the theory of quantum mechanics itself, Frank argues that the theory can be separated from its ‘spiritualistic’ and irrational associations.

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[15] On *Lebensphilosophie,* and the attitude of logical empiricism to *Lebensphilosophie*, see Vrahimis (2021).

5. Bohr and the Vienna Circle

In 1936, the Second International Congress for the Unity of Science took place in Copenhagen, with the central theme "The problem of causality – with special consideration of physics and biology". The congress was organized primarily by Otto Neurath and Jørgen Jørgensen, and featured a lecture by Niels Bohr and an opening reception at Bohr's home (Stadler 2001, Faye 2010).

The motivation behind the congress and behind Bohr's participation was to clear up misunderstandings about quantum mechanics and find an agreement about its philosophical implications. Before the conference, Bohr exchanged several letters with Frank and Neurath, both of whom he had met before and knew personally. Both Frank and Neurath warned Bohr that his writings could easily be misunderstood to support a mystical point of view. Neurath wrote to Bohr that he had read Bohr's writings with great interest, but had found several passages "which *under all circumstances must give rise to misunderstandings*, and indeed do so".[16] Frank similarly wrote to Bohr that although he was convinced that Bohr did not support the mystical interpretations of quantum mechanics, it was important to avoid misunderstandings:

> If I (...) often see a risk of misunderstanding in your manner of expression, this is due to the following: today there are everywhere forces at work which want to replace modern natural science with something of the type of medieval scholasticism, and thereby also to spiritually reinforce the various medieval-barbaric political systems. To be convinced of this, one only needs to read the new "Zeitschrift für die gesammte Naturwissenschaft", published by the Vieweg publishing house in Braunschweig, which is supposed to be a kind of National Socialist competition to the journal "Naturwissenschaften". Here, modern physics is being used quite openly to support a backward and barbaric worldview.
> I believe that it is the duty of every physicist to always express himself in such a way that it is impossible to misuse his work. In my opinion, this can only be done through the development of a consistently positivistic, or, if you will, physicalistic terminology, which is applicable in physics as well as in psychology.[17]

Frank writes that he is aware of the fact that when a theory is still in development, it is not always possible to express everything clearly and unambiguously, and that the demand of giving clear definitions of all concepts can hinder scientific research; "But once a result has been obtained, it must be possible to express it in such a way that it is no longer possible to misuse it".[18] In another letter, he specifically mentioned Jordan as someone spreading dangerous misinterpretations: "You can see from the new brochure by Jordan what confusions often arise, that people are trying to exploit quantum mechanics in favor of the National Socialist worldview and even their race biology. In contrast, it seems to me to be extremely important that we agree on formulations that exclude such misuse".[19] Here, Frank probably referred to Jordan's *Physikalisches Denken in der neuen Zeit*, in which Jordan combined an

[16] Neurath to Bohr, 19 Nov 1934 - Niels Bohr Archive, Copenhagen.
[17] Frank to Bohr, 1936 - Niels Bohr Archive, Copenhagen.
[18] Frank to Bohr, 1936 - Niels Bohr Archive, Copenhagen.
[19] Frank to Bohr, 9 Jan 1936 – Niels Bohr Archive, Copenhagen.

exposition of the implications of quantum mechanics with Nazi ideology and emphasized the military importance of science, including the possibility of atomic bombs (Jordan 1935b).

Both Neurath and Frank wrote to Bohr that they thought they were essentially on the same page: "Of course, our basic attitudes coincide to a large degree and I think that certain differences can easily be resolved"[20]; "I completely agree with you that we could agree about all these questions if we had the occasion to talk about them in detail".[21] Also Bohr expressed the wish to clear up misunderstandings related to quantum physics, and the hope to reach a complete agreement.[22] Bohr had his own agenda for his interactions with logical empiricists, and tried to convince them of the general epistemological significance of his conception of complementarity (Faye and Jaksland 2021b). Moreover, he was eager to free himself from the association with Jordan, who presented his ideas on biology and psychology as an elaboration of Bohr's ideas. In 1934, the quantum physicist and molecular biologist Max Delbrück had reported to Bohr about a lecture given by Jordan at the Berlin Society for Empirical Philosophy, which was poorly received, especially by the biologists who attended the lecture. In the discussion, Jordan's views were criticized together with those of Bohr, and "The result was that subsequently, all the biologists scolded all the physicists" (Delbrück to Bohr, Nov 1934, cited in Sloan 2011, 71).[23] Thus, for Bohr, the Congress for the Unity of Science offered a welcome opportunity to clarify his views on the implications of quantum mechanics and to dissociate himself from Jordan as well as from any mystical and otherwise unscientific interpretations.

Even more than at the previous meeting of the unity of science movement in Prague, the atmosphere at the congress in Copenhagen was affected by the political situation. Several people who had wanted to attend the congress were not able to go, because they already emigrated from Europe. Moritz Schlick had not been able to obtain a permit to travel to Copenhagen and thus had to stay in Vienna, where, while the congress was taking place, he was murdered by a deranged former student, on the stairs of the university. His death was announced during the congress, to great shock of the participants. Schlick's murder was to get an ugly political aftermath (Stadler 2001).

Pascual Jordan did attend the congress, but only after some hesitation. He had to apply for permission for attending the congress with the Nazi authorities, and in his application expressed doubts about whether he would actually go, adding: "Some of the expected foreign participants of the congress have adopted an adversarial attitude towards my views, which is partly due to different ideological positions" (Jordan to the Reich Education Ministry, quoted in Hoffmann and Walker 2007, 97-98). But although Jordan did not feel like participating and exposing himself to criticism, he may have found that he did not have a good excuse to be absent, since Bohr had explicitly invited him and the congress took place immediately after a large physics conference in which he was participating in any case. After the congress, Jordan provided generous information about the ideologies, political leanings and race of the other

[20] Neurath to Bohr, 19 Nov 1934 – Niels Bohr Archive, Copenhagen.

[21] Frank to Bohr, 1936 - Niels Bohr Archive, Copenhagen.

[22] Bohr to Frank, 27 May 1936 – Niels Bohr Archive, Copenhagen.

[23] After the war, Jordan's views on quantum biology became more moderate, and his interactions with biologists more fruitful (see Beyler 1994).

participants to the Nazi authorities (Hoffmann and Walker 2007; Hoffmann and Walker 2020).

The first lecture at the conference was by Bohr, who expressed the aim to clarify his ideas on complementarity and its possible role in biology and psychology: "Since (...) the opinion has been expressed from various sides that this attitude would appear to involve a mysticism incompatible with the true spirit of science, I am very glad to use the present opportunity of addressing this assembly of scientists working in quite different fields but united in their striving to find a common ground for our knowledge, to come back to this question, and above all to try to clear up the misunderstandings which have arisen" (Bohr 1936/1937, 293/289). Bohr emphasizes that his conception of complementarity does not enable a spiritualist interpretation of quantum mechanics and "rejects every compromise with any anti-rationalistic vitalism" (Bohr 1936/1937, 301/296). Bohr's lecture was followed by lectures by Frank and Schlick, the latter read in Schlick's absence. Both Frank and Schlick also strongly emphasized that no such conclusions followed from quantum mechanics.

Schlick's lecture was titled 'Quantum theory and the knowability of nature'. In this lecture, he addressed the issue of whether, as was often claimed at the time, quantum mechanics poses a fundamental limit to scientific knowledge.[24] A major reason for this claim was that the theory of quantum mechanics is not a causal theory in a classical sense, and in particular that it is not deterministic: it can merely give statistical probabilities for measurement outcomes. The idea of a fundamental limit to science was given a more exact formulation with Heisenberg's uncertainty relations, which Heisenberg introduced in 1927, and which state that there is a limit to the accuracy with which the position and momentum of a particle (e.g. an electron) can be predicted: the more precisely the position is given, the less precisely one can predict the outcome of a measurement of the momentum, and vice versa. This undermines classical determinism, and seemed like a mathematically exact and scientifically proven *Ignorabimus* (to use the famous term introduced by Emil Du Bois-Reymond in 1872, 'we will not know'). The claim that the Heisenberg uncertainty relations presented a fundamental limit to science was not uncontested: according to the physicist Max Von Laue (an old friend of Schlick) it merely presented "the physical effect of that general, deep cultural pessimism that forms a basic mood of our time" (Von Laue 1934, 401). The claim that there is a fundamental limit to scientific knowledge was in conflict with the scientific world conception of the Vienna Circle, according to which there is nothing which is principally unknown. Carnap had argued in *The Logical Structure of the World* that "Science, the system of conceptual knowledge, has no limits" (Carnap 1928/2003, 290), and Frank had added to this that "Science has no limits and every place left open by it immediately falls into the hands of anti-scientific forces" (Frank 1932/1988, 39).

However, in 1931, Schlick had argued that the philosophical implication of the Heisenberg uncertainty relations is that science sets its own limit. He argued that the Heisenberg uncertainty relations presented a limit to predictability and thereby to causality, and he presented this as a striking confirmation of empiricism: "The fundamental progress is

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[24] Schlick mentions Eddington as an example: Eddington had argued on the basis of quantum mechanics that physics can only describe certain aspects of nature, namely that which is measurable (Eddington 1929, 258ff).

clear: we can now speak *in the same sense* of an empirical test of the principle of causality as of the test of any special law of nature” (Schlick 1931, 153).[25]

In his lecture in Copenhagen, Schlick noted that some authors had welcomed the idea of a limit to the knowability of nature, “because they thought that in this way they would find room for certain favorite metaphysical ideas, such as the so-called freedom of the will or the acceptance of spiritual ‘substances’” (Schlick 1936, 317). But, Schlick asks, what exactly does it mean to say that something is unknowable? Usually, this means that there is something which remains hidden to us, that there is a meaningful question which we cannot answer. But, according to Schlick, this is not the case in quantum mechanics. The limit to knowledge which quantum mechanics presents us is not an arbitrary limit to our cognitive capacities, but represents an objective feature of nature.

Here, Schlick connects to discussions about the interpretation of the Heisenberg uncertainty relations, which also formed a main theme in the lectures of Bohr and Frank. Heisenberg himself (at least initially) explained his uncertainty relations through the idea that in quantum mechanics, it is not possible to observe a system without disturbing it. In particular, when the position of a particle, such as an electron, is measured, its momentum necessarily gets disturbed in the process, and vice versa (Heisenberg 1927). This idea of disturbance during measurement implies that an electron does in fact have a well-defined position and momentum at every instant, but that it is fundamentally impossible to know these. This would mean that the Heisenberg uncertainty relations present an arbitrary limit to our capacities of observation, that we cannot observe quantum systems as they really are, and that there are meaningful statements which are unverifiable (such as: “the electron at time t has position x and momentum y”).

Schlick, however, rejects this conclusion, and argues instead that it is meaningless to ask about the exact values of the position and momentum of a particle at an instant: the terms ‘position’ and ‘momentum’ can simply not simultaneously be applied. The same argument was made by Bohr and Frank: all three argued that it is therefore misleading to explain the

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[25] Schlick argues that the principle of causality should ultimately be understood as a heuristic principle in science, namely the principle that we should always keep looking for causes. As such, it is strictly speaking not the case that this principle has been empirically falsified in quantum mechanics, since a heuristic principle cannot be true or false; rather, according to Schlick, what quantum mechanics had unexpectedly revealed was that this principle was not purposive within quantum mechanics, at least not within the limits set by the Heisenberg uncertainty relations (Schlick 1931).
In 1925, Schlick had still objected to the conclusion that strict causality has to be given up in quantum mechanics, because he regarded causality as a precondition for science. Schlick argued that only “in the case of utmost emergency” we could accept pure chance in nature, because this would mean that “complete knowability is relinquished”: accepting pure chance would mean to stop looking for causal relations between phenomena, and thereby to put a halt to scientific research altogether (Schlick 1925, 461). For Schlick, causality was essentially equivalent to determinism, and the challenge to formulate an empirically testable principle of determinism ultimately led him to define determinism in terms of predictability (Schlick 1931; Placek 2014). This then meant that a limit to predictability is at the same time a limit to causality, and thereby to science itself. But with the Heisenberg uncertainty relations, exactly such a fundamental limit to the predictability of the position and momentum of particles was introduced.

Heisenberg uncertainty relations in terms of disturbance during measurement. Frank argued: "This representation, in which the states of the mass particles play the role of the 'thing in itself' in idealistic philosophy, leads to innumerable pseudo-problems" (Frank 1936b, 307).[26]

In the printed version of his lecture, Bohr referred to Heisenberg's uncertainty relations as 'indeterminacy relations', exactly to indicate that there is not merely a limit to the accuracy with which we can know the position and momentum of a particle, but that exact values of position and momentum cannot be simultaneously attributed to it (Bohr 1936/1937, 292; Faye 1991, 188). The previous year, Bohr had been confronted with the EPR-paradox, a challenge to the completeness of quantum mechanics, posed by Einstein, Podolsky and Rosen. In order to deal with this challenge, Bohr emphasized in stronger terms than before that we can only attribute properties to a particle within a specific experimental setting. Since the experimental setting needed to attribute a position to a particle and the experimental setting needed to attribute a momentum to the particle exclude each other, the expressions "position of a particle" and "momentum of a particle" are complementary: they are not simultaneously applicable (Bohr 1936/1937; Frank 1936b; Faye 2010).

Whereas Bohr thus started using the term 'indeterminacy' instead of 'uncertainty', Schlick objected to the idea that the position and momentum of a particle are indeterminate, and only get a determinate value through measurement: he argued that it is simply not clear what it would mean for a position to be indeterminate. It seems that Schlick objects specifically to the idea that a particle has inherent properties which are somehow vague or blurry, a conception which also Bohr would reject. A few years earlier, Schlick had already objected to the idea that we can attribute an 'indeterminacy' or 'fuzziness' [*Verschwommenheit*] to nature itself (Schlick 1931, 161).

Thus, it indeed seems that Bohr, Schlick and Frank were essentially on the same page: they agreed that is meaningless to speak about e.g. the position of an electron independently of measurement. In their lectures in Copenhagen, all three were primarily concerned with clearing up misunderstandings connected to quantum mechanics, and offered a common account with which it could be maintained that, even if we cannot make exact predictions for the values of all quantities in physics, this cannot be taken to mean that there is something which remains outside the limits of science. If Heisenberg uncertainty relations set a limit to science, this was simultaneously a limit to what could meaningfully be spoken about: "The quantum laws lay claim to a complete, exhaustive description of nature in the sense that in principle they say *everything* that can be said in any language about any natural process" (Schlick 1936, 319). All three argue that it is meaningless to state that there are things which are unknowable and remain hidden to us, and that the limits implied by quantum mechanics do not offer any room for speculation about e.g. free will, organic life or religion.

Neither of the lectures mention Jordan: if he was indeed a target of the arguments against misinterpretations of quantum mechanics, he remained an implicit target. It has to be noted that Jordan, who presented himself as a positivist, also maintained that it was

[26] Frank had mentioned one of these pseudo-problems in an earlier publication, where he argued that the fact that quantum mechanics does not yield exact predictions for the position and velocity of electrons had given rise to the attribution of a 'free will' or of vital properties to electrons, in order to explain the cause of their motion. But Frank argued that it is only traditional philosophy which makes us expect that electrons *have* an exact position and momentum at every instant (Frank 1930).

meaningless to speak about the exact values of the position and momentum of a particle in an instant; but at the same time, Jordan employed exactly the type of language about disturbance in measurement and indeterminateness as an intrinsic feature which Bohr, Schlick and Frank here rejected, and generally it was hard to see how his ideas about the relevance of quantum mechanics for biology and psychology could work if they did not invoke factors going beyond the equations of quantum mechanics. Certainly, the careful restrictions placed by Bohr, Frank and Schlick on what could meaningfully be said about quantum systems would make Jordan’s speculations impossible.

But did the agreement which Frank and Schlick reached with Bohr extend to Bohr’s own ideas about the relevance of quantum mechanics for biology and psychology? In their lectures in Copenhagen, Frank and Schlick both seemed carefully supportive of Bohr’s proposal to apply the concept of complementarity to other domains. Both object to Bohr’s claim that exact observation of the state of an organism would kill the organism: in any case, such a claim would require empirical support. Frank furthermore argues that the fact that we cannot observe our own psychological state without changing it does not present an unavoidable problem in psychology (as Bohr believed to be the case) but merely provides an argument for behaviorism: the issue can be avoided if psychological research is based on observations of the behavior of other people, rather than on introspection (Frank 1936b). But both Schlick and Frank agree that it is not unthinkable that in order to understand the workings of living organisms, we need biological concepts which are complementary to those of physics. Schlick argues that it may turn out that laws of organic life have to be “formulated with specific concepts which differ from the known concepts of physics, just like quantum concepts differ from the classical ones” (Schlick 1936, 325). Frank similarly argues that Bohr’s idea of a complementary relation between approaching an organism as a living being and approaching it as a physical system is logically unobjectionable. However, he notes that whereas the complementarity form of expression had been shown to be unavoidable in quantum physics, there are no reasons to think that it is unavoidable in biology; it merely presented a (perhaps attractive) possibility (Frank 1936b, 315).

In a certain sense, Bohr’s ideas on complementarity fit well within the program of the unity of science movement: Bohr argued that classical concepts, which he takes to be concepts from ordinary language, are indispensable for unambiguous communication about physical experiments. Therefore, also within quantum mechanics, we have to continue using classical concepts such as ‘position’ and ‘momentum’, despite the fact that these concepts are not always simultaneously applicable (on Bohr’s notion of classical concepts, see e.g. Bokulich and Bokulich 2005). One could thus take such concepts to offer a common basis for all sciences. Frank recognized this as an attractive feature of Bohr’s views, and argues that what we can learn from Bohr is that we can continue to use concepts from everyday language in order to talk about experiments in physics, as long as we impose certain restrictions on the use of these concepts: “There is no doubt that this idea is also fruitful for logical syntax in general, and deserves to be applied to other areas of science” (Frank 1936b, 316).

However, the idea that in order to describe organic processes, one needs conceptions which are complementary to those of physics, is in tension with at least some of the conceptions of the unity of science within logical empiricism. Members of the Vienna Circle held different conceptions of unity in science (Galison 2016). For Carnap (in 1928/2003), the ultimate aim was to integrate all of science into one unified and consistent framework, a view which was not easily reconcilable with complementarity, since the latter implied that there can be statements which are individually meaningful but cannot be combined; Carnap was therefore indeed critical of complementarity (Faye and Jaksland 2021b, 117). Neurath, however, had a pluralistic and encyclopedic conception of the unity of science, for which this would pose no problem. Although Frank seemed accepting of complementarity in Copenhagen in 1936, earlier that year in Paris he had expressed himself more critically of complementarity and had argued: "If, in the regions touching upon both physics and biology, one notices some confusions, these arise from the fact that in these two sciences one does not speak the same language. These difficulties show us the need to create a language common to all sciences, thanks to which alone it will be possible to formulate with full clarity the problems of the fields which touch upon two or more of them" (Frank 1936a, 3). This argument directly went against the idea that there can be biological concepts which are complementary to the concepts of physics. Thus, if Frank in Copenhagen found the idea of a complementary relation between physics and biology acceptable, this was a recent conversion.

But whereas the idea that there can be a complementary relation between concepts of biology and concepts of physics was compatible with at least some conceptions of unity of science in logical empiricism, a bigger problem was posed by Bohr's conviction that organic life ultimately remains unexplainable, which again brought in the idea of a fundamental limit to the scope of science.

In Copenhagen, both Bohr and Frank seem to have made an effort to present a common account of the implications of quantum mechanics, and to emphasize the points on which they were in agreement. Bohr concluded his lecture by saying: "I hope (...) that I have to some extent succeeded in giving you the impression that my attitude is in no way in conflict with our common endeavors to arrive at as great a unification of knowledge as possible by the combating of prejudices in every field of research" (Bohr 1936/1937, 303). And Frank said in his closing words: "It has sometimes been claimed that there is a certain opposition between the views of logical empiricism and Bohr's conception of quantum mechanics. I think that it has been made very clear at this congress that this is not the case" (Frank 1936c, 445). Frank argued that Bohr was in full agreement with logical empiricism in his rejection of metaphysics, "even if there are still differences regarding the more hypothetical prospects for the applicability of the notion of complementarity to psychology and biology" (Frank 1936b, 446).

However, as much as Schlick and Frank wished to present a common account with Bohr, they could ultimately not fully go along with Bohr's views on biology. Schlick, in his lecture, strongly rejects Bohr's idea that organic life remains ultimately unexplainable: just like in quantum physics, we are not justified to assume the existence of anything which remains unknown to us, we should also not conclude that there is anything mysterious or unknowable about organisms (Schlick 1936). And although Frank agreed with Bohr that it may be impossible to account for organic phenomena in terms of current physics, it seems that he thought that in this case we would need to develop new concepts which go beyond current physics, and with which both physical phenomena and phenomena of life can be described.

A report of the conference in Copenhagen notes that "the diversity of points of view obscured at times even the ultimate goal so pointedly expressed in the very name of the Congress" (Werkmeister 1936, 593). The report states that the differences between the views of Bohr and Frank became more clear in the discussion: "In the discussion, *Popper* showed that the difference between the views of Bohr and those of Frank lies in this: that Frank believes a generalized physics to be able to cope with the problems of life, whereas Bohr maintains that life is unique and cannot be dealt with in the manner in which we analyse inorganic matter" (Werkmeister 1936, 595).

Thus, whereas Frank and Schlick allowed for the possibility of a complementary relation between the current concepts of biology and those of physics, they could not accept the implication of a fundamental limit to our understanding of organic life, even though for Bohr, this was perhaps the central point.

After the conference, the optimism about finding a common interpretation in order to put aside all misunderstandings connected to quantum physics seemed to have lessened. There had been a proposal to publish the lectures of Bohr, Schlick and Frank together as an independent booklet, but by the end of the year, Bohr wrote to Frank that he had serious doubts about this proposal, since he thought that the three lectures were not sufficiently in agreement with each other.[27] The booklet never appeared. In the following years, Bohr remained in contact with some of the logical empiricists, and persisted for some time in his efforts to convince them of the significance of complementarity as a general epistemological principle, though ultimately not successfully (Faye and Jaksland 2021b). Bohr remained involved in the unity of science movement for some time: he was part of the advisory committee for the *Encyclopedia of Unified Science*, and contributed a one-page essay to its first volume (Bohr 1938). After the war, he wrote several articles on the topic of unity of science, in which he argued for interconnections between all sciences (Bohr 1955; Bohr 1960). However, by then it had become clear that Bohr's approach to the issue of the unity of science, which continued to be based on the notion of complementarity, was essentially different from that of the logical empiricists.

The attempt of Frank and Schlick to form an alliance with Bohr, in order to present a clear account of quantum mechanics which offered no room for interpretations they regarded as spiritualist, mysticist or irrational, had been partially successful, and Bohr agreed with Schlick and Frank that quantum mechanics offered no room for speculations going beyond observation. But in the end, also Bohr argued that quantum mechanics had philosophical implications which Frank and Schlick could not accept.

Concluding remarks

In historical accounts of the foundations of quantum mechanics, the names of Frank and Schlick are not often found, and it seems that they have not made lasting contributions to this field. However, contributing to a better understanding of the foundations of quantum mechanics was not their only concern, and in any case for Frank it was not his main concern. Rather, he was concerned with the ways in which quantum mechanics was used to support

[27] Bohr to Frank, 21 Dec 1936 – Niels Bohr Archive, Copenhagen.

certain world views: he argued in particular that quantum mechanics provided no basis to argue for the irreducibility of the mind or organic life. For Frank, this was a project with social and political relevance, and formed one way to defend rational scientific thinking in a time of increasing irrationality. Although other members of the Vienna Circle did not write about the issue as extensively as Frank, when they did speak about quantum mechanics they often showed a similar concern for the question what broader conclusions could legitimately be drawn from it. Frank's writings on quantum physics can thus be seen as an example of the ways in which logical empiricism in this period aimed to be socially relevant, even with a topic as seemingly remote from social concerns as quantum physics (on the issue of social relevance in logical empiricism, see Reisch 2005).

It can be argued that also this project, to set limits to quantum speculations, was ultimately not very successful. Notably, the attempts of the Vienna Circle to find an ally among leading quantum physicists were not very successful: only Jordan and Bohr showed a serious interest in logical empiricism, but Jordan's views were otherwise quite opposed to those of the Vienna Circle, and also Bohr's ideas on complementarity proved hard to reconcile with logical empiricism. Among the leading quantum physicists, those who were strongly opposed to quantum mysticism and speculations probably had no patience for philosophy in general, and showed no interest in the efforts of logical empiricists to set limits to what can meaningfully be said.

Despite the apparent lack of lasting success, the writings of Frank and Schlick on quantum mechanics may be of interest in pointing us to a role which philosophy of physics can have, but nowadays does not often take, namely a critical engagement with popular writings on physics, and with implications drawn from physics for other areas of knowledge (or life). The primary targets of their criticism were philosophically-minded scientists, who, often writing for a popular audience, drew far-ranging and speculative implications from quantum physics. Nowadays, the amount of 'quantum speculations' is certainly no smaller than it was in the 1930s,[28] and a professional philosophical engagement with speculative ideas drawn from quantum physics is often lacking.

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[28] On speculation and mysticism in popularizations of quantum mechanics, see e.g. Dieks (1996), Bricmont (2017).

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