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Article

Understanding Futures of Science: Connecting Causal Layered Analysis and Philosophy of Science

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Abstract

This paper analyses the similarities and connections between philosophy of science and causal layered analysis. The paper points out that philosophy of science can be understood as a kind of causal layered analysis of science. These similarities and connections mean that the insights in philosophy of science can be used to investigate the important but neglected topic of possible futures of science. The connections make it possible (i) to open up the present and past to create alternative futures of science, and (ii) to reveal deep worldview commitments behind surface phenomena in science-related discourses.

Keywords

Future of Science; Philosophy of Science; Causal Layered Analysis; History of Science

Introduction

This paper analyses the connections and similarities between (i) philosophy of science as a field that analyses science and our conceptions of it, and (ii) causal layered analysis (CLA) as a method that "opens up space for the articulation of constitutive discourses" (Inayatullah, 1998, p. 815; see also Inayatullah, 2004; Inayatullah & Milojevic, 2015). These similarities and connections indicate that the insights in philosophy of science can be used to investigate the important but neglected topic of the possible futures of science. Philosophy of science has improved our understanding of science, but this understanding has not been developed into future-oriented thinking. In this paper, it is argued that one way to remedy this shortcoming is to connect philosophy of science and CLA. Understanding the connections and similarities between philosophy of science and CLA makes it possible to conceive philosophy of science as a kind of CLA that (i) uses analytical tools that are similar to the poststructural toolbox, and (ii) has already provided insights on mythic/metaphoric, structural, and causal levels of science and our conceptions of science.

Explicating the relationship between CLA and philosophy of science makes it possible to open "up the present and past to create alternative futures" and to reveal "deep worldview commitments behind surface phenomena" (Inayatullah, 1998, p. 815) with respect to the possible futures of science. The analysis of different levels in philosophy of science reveals that our conceptions concerning the development and possible futures of science are products of the interplay between deep convictions, theories, and explanations. Awareness of this interplay enables us to critically engage with the conceptions. Moreover, the analysis of similarities between the CLA as a poststructural toolbox and philosophical analysis indicates how the conceptual tools of philosophy of science enable us to critically approach the culturally received conception of science. These tools enable us to challenge dominant accounts of the scientific past, present, and future. To avoid confusion, it is important to highlight that the aim of this paper is not to perform a CLA of philosophy of science but to show how philosophy of science has already provided insights that correspond to those that CLA achieves. Given this tight connection, it follows that if CLA is

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a viable method to study the possible futures and our conceptions behind them, then insights from philosophy of science can deepen our understanding of the possible futures of science.

Opening up the present and past of science to create alternative futures and revealing deep worldview commitments with respect to science and the future of science is important for three reasons.

First, science has changed considerably during its history. Not only have the contents, methods, goals, and assumptions changed but so have its technological, social, and cultural settings. Moreover, many, if not most, aspects of science are dependent on these settings. The technological, social, and cultural settings are in constant flux and it seems reasonable to conjecture that the rate of technological, social, and cultural change will increase in the 21st century. The conclusion, that (at least some aspects of) science will therefore also change in the future, follows immediately.

Surprisingly, very little has been said about the estimating[1] of possible futures of science (or sciences, to be exact). Only fragmented lines of thoughts concerning the estimating of the future of science are present in the literature (e.g. IFTF, 2006; Rescher, 1984; Martin, 1995; McIntyre, 2007; Popper, 1957; Small et al., 2014; Tromp, 2018). Moreover, while there are many reports (e.g. Joanny et al., 2020; Reding and Eaton, 2020) that summarize possible future topics and methods in science, there has been little reflection on how the future of science can be estimated in a systematic way. As philosophy of science has shown, science is opaque and difficult to understand. Given the opaqueness, the reports concerning the future of science appear hopelessly simplistic without reflection on the conceptions of science that they embrace. The problem is that philosophy of science has not been of much help here. Even though history and philosophy of science have deepened our understanding of science, explicit conceptual tools to understand the estimating of possible futures of science are missing from its repertoire.

A similar blind spot with respect to the future of science can be found within futures research. No comprehensive approach to the development of scientific practices from the past to the future exists. Such a comprehensive approach should integrate different elements that shape scientific practices at different levels. Scientific practices consist of an intertwined web of theories, models, concepts, ontological assumptions, values, methods, instruments, means of communication, and so on. The nature of the different items on the list varies between different periods and different scientific subfields. The complexity and heterogeneity that characterize science and its history are difficult to tame intellectually and the first step towards the management of the complexity should be acknowledging it. Still, the idea of a "modern science" as some sort of a monolith dominates the futures research. For example, in their classical work, Funtowicz and Ravetz (1993) treat what they call "normal science" as a monolith that will be challenged by another understanding of what science is. This is called "post-normal science". The characterization has two problems that are common in the discussions about science. First, it is based on one conception of science, a Kuhnian one. Secondly, it simplifies the conception in order to provide a straightforward vision for the future. For example, in Kuhnian theory, it is not the case that normal science "is unexciting, indeed anti-intellectual" or that in the "'normal' state of science, uncertainties are managed automatically [and] values are unspoken", as Funtowicz and Ravetz (1993, p. 740) claim. Kuhn explicitly states that there is no agreement on the application of values in cases involving risks (1970, p. 186). It is difficult to understand what kind of alternative future the concept of post-normal science constructs when its basic conception of actual science is so simplified and unchallenged by alternative conceptions. Given these difficulties, it might be that the whole enormous discourse about post-normal science is built upon challenging science that never existed and modifying a conception that was never held. At least, we would need subtler distinctions between different sciences and different levels of science in order to understand the implications of post-normal science and the contrast between it and previous science. In terms of CLA, the existence of some monolith science is a myth that is often repeated and hinders us from understanding science-related issues in the futures research. In order to remedy the dominance of such myths, we need to systematically study the nature and development of science from a future-oriented perspective.

Secondly, the future of science is too important a topic to be left without attention. There are countless ways in which the futures of science and the futures of conceptions of science affect society: What technologies are available (Joanny et al., 2020; Reding and Eaton, 2020), who are considered as epistemic authorities (e.g. Mede & Schäfer, 2020), how the human-nature relations (e.g. Allen, 2018) are perceived, how to generate novel innovations (e.g. Kuhlman & Rip, 2018), and so on. The ability to anticipate and prepare for changes in many areas of life depends on the ability to estimate the future of science. Simplistic pictures of science do not enable us to achieve this goal any more than simplistic pictures about other areas of life. In order to understand possible futures of science, we need deep understanding of the nature and development of science and we have to critically analyze our conceptions of science. Philosophy of science engages with these issues and is therefore valuable when estimating possible futures of science.

Thirdly, systematic inquiry into the nature and development of science and into our conceptions of science is necessary in order to develop sound self-understanding of the nature of futures research as a field of research. It is rather difficult to locate the futures research among different sciences if one does not calmly analyze the nature and development of those sciences and the conceptions that guide our judgements about scientificity. It is too compelling to stick with simplistic conceptions of science. Even though it is not the main task of this paper to analyze the nature of futures research but the estimating of the futures of science, the paper attempts to clarify how complex and multilayered task it is to locate different branches of the futures research among other fields of research and improves the self-understanding of the field by doing so. Connecting philosophy of science and CLA provides analytical tools to critically reflect on the conceptions of science that futures research uses in its self-understanding.

In what follows, the paper argues how the CLA as theory – the "poststructural toolbox" (consisting of deconstruction, genealogy, distance, alternative pasts and futures, and reordering knowledge, see Inayatullah 1998; 2004) – already has a counterpart in the analytical tools of philosophy of science. The paper then proceeds to analyze how different philosophical analyses and debates are connected to different levels in CLA from myth to litany and points towards the interplay between these different levels. The discussion shows how philosophical analyses of science can be used to open up the present and past to create alternative futures and to reveal deep worldview commitments with respect to the possible futures of science. As the paper proceeds, it shows how it is possible to find new perspectives on both philosophy of science and CLA by studying the possible futures of science.

It is important to note, however, that the paper does not claim to exhaust all possible ways of critically engaging with the possible futures of science in terms of CLA. The paper focuses mainly on canonical western philosophy of science that has shaped the hegemonic discourses concerning the nature of science.[2] The paper aims to show how it is possible to open up the present and past and reveal deep worldview commitments even within the canons of this hegemonic tradition. However, if it is possible to challenge conceptions of science even within the narrow tradition, enriching the analyses with insights developed elsewhere (e.g. in non-western traditions) can be expected to lead to even greater transformation in our thinking about science and its future.

Poststructural Toolbox

In this section, the paper will point towards useful connections between the "poststructural toolbox" and philosophical analysis of science. The poststructural toolbox consists of deconstruction, genealogy, distance, alternative pasts and futures, reordering knowledge. Next, the paper shows how each element can be found from philosophy of science and how the insights in the field enable us to shed new light on the poststructural toolbox.

Deconstruction

Inayatullah (2004, p. 8) characterizes deconstruction as follows:

> The first concept is deconstruction. In this we take a text (here meaning anything that can be critiqued [--]) and break apart its components, asking what is visible and what is invisible? Research questions that emerge from this perspective include [--]
>
> Who is privileged at the level of knowledge? Who gains at economic, social and other levels? Who is silenced? What is the politics of truth? In terms of futures studies, we ask: Which future is privileged? Which assumptions of the future are made preferable?

Philosophy of science is essentially based on the analysis of (i.e., "breaking apart") scientific concepts, notions, and practices. Philosophy of science attempts to (a) define, explicate, and characterize concepts, notions, and practices, and (b) make visible the implicit conceptions, assumptions, and tension in our thinking. For example, philosophical analyses of causal explanation in science attempt "to make distinctions among different sorts of causal and explanatory claims, distinctions that are often overlooked by those who make such claims" and to recognize "that causal and explanatory claims sometimes are confused, unclear, and ambiguous" (Woodward, 2003, p. 7). Also, the theories of scientific development serve this purpose, as will be discussed in detail in Section 3. For example, Popper recognized that people had overlooked how easy it is to confirm a theory if it lacks real empirical content (1963). Kuhn recognized that there are scientific changes that are not accounted for by theories of linear accumulation of scientific knowledge (1970). He also recognized that scientific development requires an interplay between various elements, ranging from values to ontology to observations, and cannot be reduced to straightforward theory-observation dynamics. Finally, scientific realism argues, in its *divide et impera* strategy (see Section 3), that despite the apparent radical changes in the history of science, there has been theoretical continuity in the history of science that can be made visible through analysis of past theories (Psillos, 1999).

All the theories highlight certain aspects of science and de-emphasize others, as will be discussed in Section 3. They provide insights on what is and what should be privileged, silenced, and how the notion of truth functions in science. For example, Kuhnian theory suggests that the social aspects and cohesion of science are silenced in traditional accounts and that the notion of truth is irrelevant to our understanding of the scientific developments (1970, p. 170–171; 206).

Finally, different philosophical theories privilege different futures and prefer different assumptions about the possible futures of science, as will be pointed out in detail in Section 3.2. For example, scientific realism privileges futures where our current understanding is improved in a piecemeal manner and assumes that there probably will be continuity from the present to future science. The Kuhnian theory privileges futures with radical disruptions and assumes that current scientific paradigms might come to an end. The privileging and preferring are based on the prior analysis of the dynamics of scientific development that each theory is based on. Given how science is analyzed (or "broken apart"/"deconstructed"), different visions for the future arise. Philosophical analysis and the estimating of the future of science are linked together.

Genealogy

Inayatullah (2004, p. 8) characterizes genealogy as follows:

> The second concept is genealogy. This is not a continuous history of events and trends, but more a history of paradigms, if you will, of discerning which discourses have been hegemonic and how the term under study has travelled through these various discourses. [--]
>
> Which discourses have been victorious in constituting the present? How have they travelled through history? What have been the points in which the issue has become important or contentious? What might be the genealogies of the future?

The idea that the historical trajectory of science has shaped its nature is widely recognized in the history and philosophy of science. For example, Schickore argues that "[--] a history of the present should remain part and parcel of our present efforts to understand the sciences. Fully to understand the concepts, practices, and methodological and epistemological goals and commitments of present science, we need to trace how they have come into being"- (2011, p. 477.) Moreover, Psillos concludes that "[--] what science tells us about the world, as well as the reasons to take what it tells us seriously, are issues that are determined historically, by looking at the patterns of convergence in the scientific image of the world" (2012, p. 101.) Daston has suggested that "[the historians of science] must explain how [the distinctive] character [of science] crystallized out of practices, both intellectual and manual, designed for other purposes" (2009, p. 807).

A canonical work in the spirit of genealogy is Leviathan and the Air-Pump by Shapin and Schaffer where they ask "Why does one do experiments in order to arrive at scientific truth?" (1985, p. 3). They continue: "We want our answers to be historical in character. To that end, we will deal with the historical circumstances in which experiment as a systematic means of generating natural knowledge arose, in which experimental practices became institutionalized, and in which experimentally produced matters of fact were made into the foundations of what counted as proper scientific knowledge." (1985, p. 3.) The authors study how one discourse became victorious in constituting the present by looking at a historical point in which experimentation became an important but initially contentious part of science.

The study of important junctures in the history of science that could have led elsewhere is important with respect to the issue of inevitability vs. contingency of science. The I-C issue concerns the possibility of an alternative science. If science is inevitable, there could not be a fundamentally different science (at least not as successful science as the actual one). If science is contingent, there could be a fundamentally different science. (See Kinzel 2015). This issue is important with respect to the future of science because possible answers to it enable us to map the amount of possible change in the future of science. Moreover, identifying historical moments when things could have developed differently enables us to write genealogies of the future. If we know how the present could have been different, we are in a good position to tell how we could achieve a certain future. We can reflect on the future in the same terms as we reflect on counterfactual alternatives to the present.

Distance

Distance is characterized as follows (Inayatullah, 2004, p. 8-9):

> The third crucial term is distance. [--] Scenarios become not forecasts but images of the possible that critique the present, that make it remarkable, thus allowing other futures to emerge. [--]
>
> Which scenarios make the present remarkable? Make it unfamiliar? Strange? Denaturalise it? Are these scenarios in historical space (the futures that could have been) or in present or future space?

The major philosophical theories of science tend to distance ourselves from the current science (see Section 3). For example, Kuhnian theory forces us to take seriously scenarios where there are radical changes in science, not only on the level of theories, models, and concepts, but also on the level of methodology, ontology, and values, as all these are ingredients in a paradigm that might be replaced. Even realism does not assume that there is a straightforward development from the present science to the future science. First, it is not committed to the approximate truth of theories whose success is unclear. Secondly, even the most successful theories might be replaced with theories that preserve only certain parts of the current theories and rethink other components. That philosophy of science distances us from the current science is a rather automatic consequence from the fact that the field does not take for granted received views of science but attempts to analyze science in its complexity.

The historical analyses of science that were discussed in the previous subsection also distance us from the present science. For example, Shapin and Schaffer distance us from the experimental tradition by denaturalizing its origins, as was pointed out above. Another example is Bowler's Darwin Deleted where he analyses "What would a world without Darwin look like?" (2013, p. 8). Bowler explains: "My interest in exploring what happens in a world without Darwin is driven by the hope of using history to undermine the claim that the theory of natural selection inspired the various forms of social Darwinism. The world in which Darwin did not write the Origin of Species would have experienced more or less all of our history's social and cultural developments. [--] We need to think harder about the wider tensions in our culture responsible for the ideologies that came to have the inoffensive Darwin as their figurehead." (2013, 10-11 [emphasis added].)

Finally, there are metalevel discussions in philosophy of science about the limits of our ability to distance ourselves from the present science:

First, in the inevitability vs. contingency issue, it has been suggested that, in order to know whether there really could be successful alternative science, one should build one. This is known as the "put up or shut up" argument (Soler, 2015). The obvious problem with this argument is that establishing a scientific tradition requires enormous resources. The lack of alternative science might not tell us anything about the plausibility of the alternatives but only about the allocation of resources.

Secondly, Stanford (2006) has argued that we simply are not able to conceive alternative theories and therefore our own theories appear so compelling in the face of the evidence. This argument is based on historical considerations and is known as "the problem of unconceived alternatives".

Thirdly, Tambolo (2020) has pointed out that even counterfactual histories may not be able to distance us from the present science. The problem is that, in order to construct a counterfactual narrative, we need knowledge of how the world works. Given that the actual science provides this knowledge, the present science leaks into the counterfactual narratives thus shaping their direction towards the present state of science.

It follows that, while philosophy of science can distance us from the current science, there might be general limitations to the ability to make the present remarkable. However, one should not be demoralized by this. Rather, the arguments should be seen as a crucial methodological insight: Even if we cannot (in some cases) distance ourselves from the present world, it does not follow that the present world is inevitable and the only possibility. The present world might look inevitable only because we do not have the tools to think it away.

Alternative pasts and futures

Alternative pasts and futures are characterized as follows (Inayatullah, 2004, 9):

> Futures studies has focused only on alternative futures, but within the poststructural critical framework, just as the future is problematic, so is the past. The past we see as truth is in fact the particular writing of history, often by the victors. The questions that flow from this perspective are [--]
>
> Which interpretation of past is valorised? What histories make the present problematic? Which vision of the future is used to maintain the present? Which undo the unity of the present?"

In philosophy of science, there has been a long debate about testing the philosophical theories against the history of science. This debate has shown that it is extremely difficult to choose one theory over another by confronting them with historical evidence. The many problems are summarized recently by Bolinska and Martin (2020). One straightforward problem is that philosophers of science can choose historical cases that support their theory. It is possible to highlight certain episodes in the history of science that make the theory look appealing. Deeper problems arise with respect to the interpretation of historical episodes. Lakatos (1971) famously suggested that we should rationally reconstruct the history of science; We need to explain as much of the history of science as we can in terms of a philosophical account. The more of the history of science an account deems rational, the better the account is. The obvious worry with this theory-driven approach is that it seems to lead inevitably to a distortion of the past. Why should historical reality conform to our philosophical theories? It has been pointed out that this worry is rather naïve. A philosopher of historiography Kuukkanen has argued that "All history writing includes a theoretical basis of some kind and is indeed normative, implying selectivity and emphases on what is important and explanatory in history. [–]. [Lakatos unlike others] explicitly accepted that the same historiographical data can be brought into several alternative accounts [--]." (2017, p. 91.)

If one conceives the philosophical theories as worldviews and descriptions of the possible structures (the third level of CLA, see the next section), the problems associated with historical thinking turn out to be strong methodological tools rather than problems. First, when we have scenarios of the futures of science that are based on a particular worldview, we can critically engage the historical interpretations that justify the worldview. We can ask what cases are chosen and what interpretations are influenced by that worldview and find out which cases it ignores and what alternative interpretations are possible. Secondly, it needs to be noticed that many scenarios of the future of science are shaped by theoretical interpretations. Even if a scenario appears natural, we have to explicate its theoretical underpinnings and ask how alternative theoretical frameworks would construct alternative scenarios. Awareness of the interpretive frameworks makes it possible to move between alternative histories and alternative futures. There is a shared epistemic ground between different presentations of the past and different presentations of the future.

Reordering Knowledge

Reordering of knowledge is characterized as follows (Inayatullah, 2004, 9):

> Reordering knowledge is similar to deconstruction and genealogy in that it undoes particular categories;

> however, it focuses particularly on how certain categories such as 'civilization' or 'stages in history' order knowledge. [--]
>
> How does the ordering of knowledge differ across civilization, gender and episteme? What or Who is othered? How does it denaturalise current orderings, making them peculiar instead of universal?"

Philosophy and history of science are especially well equipped to conduct such analysis. For example, the core idea in the Kuhnian theory is that different stages in history, paradigms, differ radically in their assumptions about "the right" methodology, values, and ontology. Moreover, it was shown above how genealogy and distance in philosophy of science involve analysis of historical origins and contingencies in the development of the present science. These analyses denaturalize current orderings and make them peculiar.

There has also been a shift from history of science to history of knowledge, a shift that acknowledges the historical contingency and peculiarity of science. History of knowledge does not focus only on academic settings but also on the production of knowledge in settings that are far removed from the academic ones (Renn, 2015). Moreover, history of knowledge is not merely interested in how knowledge has been produced and understood in different social and historical contexts, but it also analyses the processes that shaped how different forms of knowledge were classified and valued and how hierarchies of forms of knowledge were established (Mulsow, 2018, p. 180). In this way, philosophy and history of science and knowledge enable us to understand how knowledge has been ordered in the past and how the current ordering might not be a self-evident part of the future of science.

The Levels of CLA

While the above section was focused on the poststructural toolbox – as an aspect of the theory of CLA - we now shift focus to the four levels of CLA, that is, CLA as a method. The method of causal layered analysis (CLA) "is concerned less with predicting a particular future and more with opening up the present and past to create alternative futures" (Inayatullah, 1998, p. 815). It is a "method that reveals deep worldview commitments behind surface phenomena" (Inayatullah, 1998, p. 815.). CLA consist of analysis in/of four levels:

> The first level is the 'litany'—quantitative trends, problems, often exaggerated, often used for political purposes. [--]
>
> The second level is concerned with social causes, including economic, cultural, political and historical factors. [--]
>
> The third deeper level is concerned with structure and the discourse/worldview that supports and legitimates it. [–] The task is to find deeper social, linguistic, cultural structures that are actor-invariant [--]. Discerning deeper assumptions behind the issue is crucial here as are efforts to revision the problem. [--]
>
> The fourth layer of analysis is at the level of metaphor or myth. These are the deep stories, the collective archetypes, the unconscious dimensions of the problem or the paradox. [--] This level provides a gut/emotional level experience to the worldview under inquiry. The language used is less specific, more concerned with evoking visual images, with touching the heart instead of reading the head. (Inayatullah, 1998, p. 820).

In what follows, the paper argues how philosophy of science has already provided insights on these different levels with respect to science and our conceptions of science. Philosophical research has mapped (i) myths and metaphors, (ii) possible structures that guide scientific development, and (iii) causal factors that shape science. Moreover, while philosophy of science is not directly producing litany, the paper points out that there are interesting discrepancies between science-related litanies (iv) and philosophy of science. As the paper proceeds, it indicates how the items (i)-(iv) are connected to each other in philosophy of science and how this enables us to move between the different levels as required by CLA. We begin with the deepest layer of CLA and then go upwards.

Myths and Metaphors in Philosophy of Science

Instead of starting with the litany, we commence with the deepest layer of CLA and compare that with philosophy of science. In order to understand the mythic and metaphoric level in philosophy of science, it is useful to consider as illustrations three famous philosophical theories about the core methodology, goals, and possibilities of science: falsificationism, Kuhnian revolutions, and scientific realism. This subsection discusses the mythic and metaphoric issues behind these theories. The theories themselves belong to the third level of CLA and are discussed in the next subsection.

Popper's falsificationism (1963) is based on the idea that science does not attempt to verify theories but falsify them. A good theory has rich empirical content that makes it possible to make risky predictions that might be false. If a prediction of the theory is false, the theory is falsified; if the prediction is correct, the theory is corroborated.

In Kuhn's theory, there are (mainly) two kinds of periods in the development of science: normal science and revolutionary science. A normal science period is a one in which a paradigm defines the research in a scientific field. A paradigm is a "universally recognized scientific achievement that for a time provides model problems and solutions to a community of practitioners" (Kuhn, 1970, p. viii). A paradigm, then, is the condition under which science can develop in a steady fashion. Revolutionary science, on the other hand, is a period in which the existing paradigm is challenged due to its inability to solve important problems and a new paradigm is established. Different paradigms are mutually incommensurable, as there are no shared standards that enable scientists to choose between competing paradigms in the period of revolutionary science.

According to scientific realism, science has been able to produce approximately true theories of a mind-independent world. Our successful and mature theories are approximately true descriptions of both observable and unobservable entities. It would be a miracle if the theories were successful without being approximately true. (Psillos, 1999.)

Popper's falsificationism and Kuhnian theory of revolutions both have an explicit anecdotal base that is appealing. There is a famous story of how Popper became dissatisfied with psychoanalysis because all human behavior could be interpreted in accordance with its theories and how, at the same period, Popper heard about Einstein's theory and Eddington's observation of the gravitational deflection which put Einstein's theory under a severe test. (See Hacohen, 2000, 93-96). Kuhn, on the other hand, has told a story of how he wondered how absurd Aristotle's physics was until he understood Aristotle's system of science as a whole and in terms different from the modern science (Kuhn, 1977, xi-xii). The theories of Popper and Kuhn can be understood in a new light by recognizing that these stories belong to the fourth level of CLA. The stories make understandable the basic convictions that the theories of Popper and Kuhn attempted to explicate: That knowledge is improved by taking intellectual risks and by abandoning one's views (Popper) or that the development of science introduces fundamental changes in our understanding of the world and that "the proponents of competing paradigms practice their trades in different worlds" (Kuhn, 1970, p. 150). Realism, on the other hand, has been (somewhat critically) summarized in a metaphor of desk-thumping, foot-stamping shout: "What then of the realist, what does he add to his core acceptance of the results of science as really true? [...] what the realist adds on is a desk-thumping, foot-stamping shout of 'Really!'" (Fine, 1984, p. 97). Another famous slogan for realism that explicates the basic conviction is "if you can spray them, then they are real" (Hacking, 1983, p. 23). The existence of myths, metaphors, anecdotes, and slogans means that philosophy of science is already involved in the revealing of "deep stories" that shape our understanding.

As is well known, there are many criticisms for all the theories above. Just to mention some of the problems, we know that, contra Popper, all observational tests of a theory require background assumptions and simple falsification is not possible. Also, there have been, contra Kuhn, unexpected discoveries with wide-reaching consequences that did not lead to a scientific revolution, such as the discovery of the structure of DNA (Bird, 2018, §6.1.). Finally, it seems that there have been, contra realism, successful theories that were not approximately true (Laudan, 1981). The basic worldview commitments at the fourth level face problems when developed into explicit and rationally assessed theories. This indicates that their origin is independent of the explicit reasoning that attempts to justify them.

Interestingly, all the positions discussed above (i.e. realism, Kuhnian, Popperian) can be found in many science-related debates which shows how deeply they affect our conceptions of science. For example, there is a debate on whether to build and what to expect from the Future Circular Collider (FCC). Sabine Hossenfelder (2020) has argued that the cost of the FCC is too great given the chances of possible future discoveries. Michela Massimi (2020) has argued that the FCC can be defended once we understand scientific progress not in terms of "great" discoveries but in terms of excluding possibilities. The baseline of the debate concerning FFC is colored by scientific realism. "With the new machine, particle physicists want to measure its [Higgs boson] properties, and the properties of some previously discovered particles, in more detail" (Hossenfelder, 2020, para. 5). However, the Popperian and Kuhnian pictures are in the mix: For example, Massimi (2020, para. 8) explicitly argues that "particle physics community has long stopped (if ever did) following any Popperian method of hypotheses-testable predictions-falsification" and the possible future of the FCC should not be understood in those terms. Massimi (2020) also makes an important note on the scientific revolutions: The direction of a revolution is not arbitrary. Rather, a revolution can only change a field whose foundations have been examined by a long tradition of detailed research.

Recognizing different myths and metaphors behind our conceptions of science is an essential step in revealing deep commitments in those conceptions. However, it is important to notice that the mythic or metaphoric core or origin of a conception does not mean that it is incorrect or benign. We need to cherish the core and, at the same time, distance ourselves from it. The cherishing means that we attempt to stay faithful to the core and understand what it might capture about science and its possible futures. Intellectual courage? Fundamental changes in the scientific worldview? Epistemic optimism? The distancing means, in this context, that we come to understand different mythic and metaphoric cores that might dominate the visions of the future of science. Moreover, recognizing the mythic and metaphoric core enables us to understand where our preferences for certain types of future comes from. Why do we want impressive experiments? Why do we want to measure the properties of particles? Finally, cherishing the mythic and metaphoric core is essential when an explicit theory of the structure of the development of science, belonging to the third level of CLA, is constructed. We need to ask what insight the theory, despite all the inevitable problems it will face, attempts to capture. Distancing is necessary at the stage of explicit theories in order to understand that a basic conviction might be incorrect in the light of critical research.

The Worldviews of Science

With respect to the third level of CLA, philosophy of science can be seen as an analysis of the structures that shape different aspects of science. The philosophical theories of science belong to the third level of CLA. As was already noted, such theories are often involved, in some form or another, in discussions about the possible futures of science. The theories describe deeper social, epistemic, linguistic, and cultural structures that are actor-invariant which constitutes the third level of CLA. This is most obvious in the case of Kuhn. His famous book was even named "The Structure of Scientific Revolutions". A paradigm is a canonical example of an actor-invariant framework. "Men [sic] whose research is based on shared paradigms are committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, i.e., for the genesis and continuation of a particular research tradition." (Kuhn, 1970, p. 11.) As was already noted above, according to Kuhn, a paradigm-driven period of normal science is followed by revolutionary science when the existing paradigm is challenged due to its inability to solve important problems and a new paradigm is established. Kuhn postulates a clear cyclic structure for scientific development. Kuhn's theory explicates the structure of scientific development and "deeper social, linguistic, and cultural processes that are actor–invariant" (Inayatullah, 2004, p. 12) and provides insights at the third level of CLA.

Scientific realists, on the other hand, tend to describe the development of science in less dramatic terms. In response to the observation that there appear to have been successful but untrue theories in history (which undermines the realists' supposed link between success and truth), realists argue that the successful theories had parts that have survived through theory-change and are true in the light of to our current theories. This is known as the *divide et impera* strategy of realism (Psillos, 1999). A similar suggestion is made by structural realists who argue that the mathematical or structural contents of successful scientific theories are preserved through theory-change (Worrall, 1989). Scientific realism seems to commit to a worldview that carries over into the visions of possible futures: despite the theory-changes in science, successful theories form a historical series where the crucial elements are preserved through theory-change. There has not been radical incommensurability between successful theories (like Kuhn thinks) and this trend will continue in the future.

The third level of CLA is fruitful with respect to the future of science because it enables us to steer clear on the tensions in our visions of the future of science. We understand that science might change in the future. Otherwise, there would be no point in investing in things like the FCC. However, it is unclear how much science will change and what to expect from the change. Usually, we expect new discoveries and improved models, and "the nightmare scenario would be a project [--] that would only reveal what some theorists call "the desert," a barren region otherwise devoid of new discoveries. (O'Callaghan, 2019, para. 9).[3] The evaluation of the possible discoveries is made in the light of current theories and is best understood in a realist's tone: We have approximately true theories that will be preserved; what we want is a more detailed picture. However, the desert might also be framed in other terms in order "to revision the problem" (see the third level of CLA): "[The] wonderful successful singular prediction of Einstein's theory was preceded by century-long vain attempts at building mechanical models of the ether. [--] Maybe the solution to some of the open problems within the Standard Model requires a revolution similar to the one behind relativity theory in rethinking the theoretical foundations for a new physics" (Massimi, 2020, para. 12). Different theories about the development of science enable us to challenge and revision any particular expectation and demand we have towards the future of science.

Systemic Causes in Scientific Development

Factors that are relevant in the development of science and explain it causally have been discussed to a great extent. These causal explanations are often related to the structural and mythic/metaphoric level of analysis. For example, Kuhn writes "How, then, are scientists brought to make this transposition [between paradigms]? Part of the answer is that they are very often not." (1970, p. 150.) Kuhn continues by citing Max Planck: "a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it" (ibid. 151). This is known as the "Planck's Principle". Interestingly, the principle has been tested recently (Azoulay et al., 2019). The finding was that "publications and grants by scientists that never collaborated with the star [eminent scientist] surge within the subfield, absent the star. Interestingly, this surge is not driven by a reshuffling of leadership within the field, but rather by new entrants that are drawn from outside of it" (Azoulay et al., 2019, p. 2917). It appears plausible that Planck Principle provides a sound causal explanation of scientific change in many cases, at least in life sciences. This speaks for the Kuhnian view.

Scientific realism, on the other hand, is committed to explaining important scientific changes in terms of theoretical and empirical insights achieved in science. For example, Psillos describes how the theoretical and experimental breakthroughs by Einstein and Perrin settled the reality of atoms in the early 20th century (2011, p. 340.) The explanation underlines the straightforward relevance of theoretical and experimental work in science that does not involve social maneuvering.

Finally, there are interesting (future-relevant) issues in science that do not stem in any obvious way from the mythic/metaphoric or structural levels of analysis. Still, studying these issues can have implications on the level of worldviews and especially on the level of myths. For example, Bedessem and Ruphy explicate "three epistemological conditions that influence the occurrence of the unexpected in the course of a scientific inquiry" (2019, p. 1). The study enhances understanding and especially challenges conventional thinking according to which "a research whose agenda is set according to external considerations is less hospitable to the full flourishing of the unexpected than a research whose agenda is freely set internally by scientists" (2019, p. 1.). Bedessem and Ruphy argue that the importation of exogenous problems may actually favor the occurrence of the unexpected.

While the study of causal mechanisms in the production of the occurrence of the unexpected does not speak for any general theory of science, it does speak against the myth (and litany, see below) that only autonomous science, free of all external influences, is able to produce groundbreaking insights. The study also enables us to reconsider structural issues related to scientific development as an interplay between theories and empirical findings. For example, it challenges the idea that science is mainly involved in theory-testing and points toward problem-solving motivations of science (see discussion in Laudan, 1977).

Litany of Philosophy of Science

The litany level does not have similar connections to philosophy of science as the other three levels, since philosophy of science does not produce litany in the same sense as it produces causal analysis, structural analysis, and metaphoric insights (as discussed above). However, as indicated above, there exists a rich level of litany with respect to possible futures of science that correspond to the first level of CLA where: "Events, issues, and trends are not connected and appear discontinuous. The result is often either a feeling of helplessness (what can I do?), or apathy (nothing can be done!), or projected action (why don't they do something about it?). This is the conventional level of most futures research that can readily create a politics of fear." (Inayatullah 2004, p. 11-12.) Quite often, the discussions about the future of science are not rigorously analyzed in the light of our best understanding of science (i.e., events, issues, and trends are not connected; assumptions are rarely questioned), as Massimi (2020) strongly emphasizes: "It is a good rule of thumb that one should not take physics lesson from a philosopher, or, equally, lessons of philosophy of science from a physicist. In either case, the risk is that the discussion is not going to be well informed." Moreover, the litany often produces "politics of fear". The framing of the future of physics as a mere "desert" (O'Callaghan, 2019, discussed above) is one example.

Table 1 below summarizes the relationship between the levels of CLA and levels of philosophy of science.

Table 1: The relationship between the levels of CLA and levels of philosophy of science

Level of CLA	**Level of philosophy science**	**The relationship between the levels**	**Popper**	**Kuhn**	**Realism**
Myths and metaphors	Anecdotes Deep convictions Slogans	↓ Ground the worldview - needs to be cherished but also distanced	Intellectual courage	Seeing world differently	"Really real!"
Worldview	Theories of science - basic dynamics/structures that shape science	↑Attempt to capture the mythic/metaphoric level ↓Provide frameworks for particular causal explanations	Falsification of theories	Paradigm-revolution dynamics	Successful science captures reality; continuity in science
Systemic Causes	Causal explanation of scientific phenomena (e.g. theory-change) in terms of a particular set of factors.	↑Are grounded on worldviews. ↑Provide evidence for/against particular worldview	E.g. crucial experiments change science	E.g. social changes affect science	E.g. explanation and experimental work shape science
Litany	Anti-philosophical, i.e. based on lack of philosophical understanding of science	↑Often based on selective or biased understanding of worldviews or causes	"Science attempts to falsify itself"	Paradigm-jargon	"We now know how things stand"

Conclusion

In this paper, it has been argued that the future of science requires systematic attention. We have a deceptive conviction that we understand what science is, but a closer look reveals a plurality in our myths, metaphors, worldviews, and causal understanding of the workings of science. In order to understand and challenge visions and scenarios about the future of science, we have to critically reflect on our conceptions of science.

The paper suggested that it is possible to conduct causal layered analyses of science on the basis of the long and diverse tradition in philosophy of science. The paper analyzed the similarities and connections between CLA – as poststructural toolbox and as the four layers – and philosophy of science and argued that philosophy of science can be understood as a kind of CLA. It was also pointed out how the methods in the poststructural toolbox have their counterparts in the philosophical and historical literature on science and how the philosophical insights enable us to answer the central questions of the poststructural toolbox. With philosophy of science, it is possible to achieve the same transformative goals as with CLA.

The paper establishes that one possible way – certainly not the only way – to study the neglected topic of the possible futures of science is to perform CLA by using insights from philosophy and history of science and science studies in general. The similarities and connections between philosophy of science and CLA indicate that if CLA is a viable method to study the possible futures and our conceptions behind them, then insights from philosophy of science can deepen our understanding of the possible futures of science. We need to futurize philosophy of science and philosophize CLA in order to understand the crucial topic of the possible futures of science. The futures of science are certainly difficult to estimate. However, the first crucial step towards such estimating is to note the complexity and diversity of (i) science itself, and (ii) especially our conceptions of science. It is necessary to analyze the history, context, underpinnings, and consequences of any conception of science in order to use it in the estimating of futures of science. Connecting CLA and philosophy of science can achieve exactly this.

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Notes

1- In the context of this paper, "estimating" means telling tentatively what could approximately happen and what is desirable to happen, given what we know about the phenomenon in question. Scenarios are a natural format to (re)present what could happen but there is no need to equate "estimating futures of science" and "formulating scenarios of futures of science".
2- This is due to the educational background of the author and canon-formation in philosophy of science. Analyzing such epistemic predicaments of philosophy of science and its practitioners would add further depth to the relationship between CLA and philosophy of science but cannot be discussed in the limits of the paper. Critical considerations about the canons of philosophy of science have received an analysis during the writing of this paper, see Bolinska and Martin (forthcoming).
3- It is interesting to note that the way O'Callaghan expresses the issue is rather metaphorical. Again, this indicates how much myths and metaphors shape the more explicit thinking about science and its future.

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