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Does Physics Need Metaphysics? A Leibnizian Approach to the Principles Underlying Natural Science

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Abstract

A number of thinkers both past and present have been skeptical of the role of metaphysics for science. The early modern philosopher David Hume denigrated metaphysics as an attempt to "penetrate into subjects utterly inaccessible to the understanding," while the Logical Positivists saw metaphysics as meaningless, wholly useless to scientific inquiry. In contrast to these thinkers stands the early modern philosopher Gottfried Wilhelm Leibniz. A mathematician and scientist himself, Leibniz developed a variety of metaphysical principles entailed centrally by his Principle of Sufficient Reason. Leibniz utilized these principles to address scientific topics of his day, including, but not limited to, the relative nature of space and the heliocentric model of the universe. Drawing on Leibniz's diverse corpus, I will reconstruct his formulations of the Principle of Sufficient Reason, the Principle of Perfection, and the Principle of the Identity of Indiscernibles, providing the intellectual context for their development. I will then argue through examples that his metaphysical principles illustrate the utility of metaphysics for natural science, for they can be used to both ground the logical coherence of the discipline of physics and serve as practical methodological guides for theory development and selection.

Keywords: Leibniz, philosophy of science, metaphysics, Principle of Sufficient Reason

Section I: Introduction

When seeking to analyze contemporary issues in the philosophy of natural science,[1] one may not think to consult early modern metaphysical thought for guidance. In fact, one may not think to consult metaphysics at all—this study was dealt a great blow in the early twentieth century by the Vienna Circle's logical positivism, the effects of which are still felt today both academically and culturally. Yet, in an era boasting an ever-expanding particle zoo, mind-boggling quantum mechanics experiments, and concerns over what causes or even counts as consciousness, one may turn again to metaphysics as a source of rational guidance. When embarking on this project of applying metaphysical thinking to the discipline of natural science, one cannot help but seek the insights of Gottfried Wilhelm Leibniz. Known as a genius polymath of the late seventeenth

[1] I will use "natural science," "physical science," and "physics" interchangeably.

and early eighteenth centuries, Leibniz wrote on questions spanning, but not limited to, philosophy, theology, physics, and mathematics. As Leibniz scholar Jürgen Lawrenz remarks, while "Newton has nothing more to tell [us], Leibniz's work is a goldmine of pioneering ideas that has not been tapped before" (Lawrenz, 2013, p.2). While Leibniz made a number of physical and mathematical advancements—ranging from an early formulation of kinetic energy to the underpinnings of calculus—he is perhaps most of interest due to the foundational metaphysical principles which guided all of his philosophical and scientific thinking (Leibniz, 1989, p. 11). In this paper**,** I will provide a thorough overview of the metaphysical principles most relevant to Leibniz's scientific pursuits, situating them within his thought. I will then argue that Leibniz's principles serve as illustrations of two ways in which metaphysics is necessary for physics—while some can be employed in efforts to ground the coherence of natural science, others can serve as practical guides to push natural science forward. Thus, while Leibniz's metaphysics is not the only possible metaphysical foundation necessary for physics, it serves as a concrete example of how metaphysics can attempt to meet the conceptual and practical needs of physics.[2]

Section II: Leibniz's Metaphysical Principles

For the purposes of this paper, I will define "metaphysics" as the study of the non-physical nature of reality using the tools of reason, and "natural science" as the "systematic and critical investigations aimed at acquiring the best possible understanding of the [physical] workings of nature" (Hansson, 2021). The Leibnizian metaphysical principles of interest in this paper are those which are most directly applicable to the foundations and practice of natural science:

(1) The Principle of Sufficient Reason (PSR)- the idea that "we can find no true or existent fact, no true assertion, without there being a sufficient reason why it is thus and not otherwise" (Leibniz, 1989, p.217)

(2) The Principle of Perfection (PoP)- the idea that God freely chose to create the best possible world, maximizing perfection by selecting the reality which facilitates maximal ontological richness through the simplest means (Leibniz, 1989)

(3) The Principle of the Identity of Indiscernibles (PII)- the idea that "to suppose two things indiscernible, is to suppose the same thing under two names" (Leibniz, 1989, p.328)

[2] The subject of this paper is not the truth of Leibniz's principles, nor the intricacies of his arguments for them. Rather, I am concerned with the logical and practical use of metaphysical principles such as these for the sciences.

In this section, I will situate each relevant metaphysical principle in Leibniz's thought, especially focusing on the foundational PSR, which I take to be the logical source of the other two principles. While the information in this section is not directly necessary for understanding my later arguments, it is helpful for grasping the thinking which led to the genesis of Leibniz's principles, as well as the manner in which one could apply them or assess their veracity.

Along with the Principle of Contradiction,[3] Leibniz holds the PSR to be one of the "two great principles" upon which "our reasonings are based" (Leibniz, 1989, p.217). For Leibniz, a necessary truth is one whose negation entails a logical contradiction; all other truths are contingent. The PSR holds for both necessary and contingent truths, as the sufficient reason for a necessary truth is its proof-based reduction to an identity (as in mathematics) or fundamentally self-identical nature (for example, "A=A"). Yet, Leibniz holds that the PSR is practically applicable to contingent truths, or "truths of fact," which can only be reduced to identities using an infinite series of reasons or causes (Leibniz, 1989, p.217-8). While it may appear that Leibniz's PSR results from his Predicate-in-Notion Principle (PIN) of truth,[4] it seems that his arguments for the PSR based on the PIN arose after his acceptance of the PSR. Though the issue is contentious, I hold the reading most faithful to Leibniz's views to be that which interprets the PSR as a fundamental axiom made apparent to us through its necessity for our reasoning, just like its logical counterpart, the Principle of Contradiction (Melamed & Lin, 2023).

When considering the PSR, a natural question arises: what counts as a *sufficient* reason? For Leibniz, a contingent truth's reason can be analyzed as a chain of efficient causes (if physical) and a chain of final causes (if metaphysical). Physical explanations must ultimately be explained by metaphysical appeals to final causes, so all truths are grounded in the metaphysical (Leibniz, 1989, p.87). Each contingent truth's chain of reasons proceeds infinitely and is itself contingent; thus, the chain of reasons for a contingent truth must itself be explained by that which is outside of, and grounds, this series. He calls this "ultimate reason of things" God, the only necessary substance (Leibniz, 1989, p.26). I thus take Leibniz to mean that each contingent truth possesses a *sufficient* reason insofar as its chain of reasons or causes involves no self-justification by a component contingent truth. So, though we know that God is the ultimate reason for all truths, we can continue

[3] This is Leibniz's name for the age-old Principle of Non-Contradiction.
[4] Through his PIN Principle of truth, Leibniz maintains that each subject logically contains within it all of its necessary and contingent predicates.

seeking reasons for contingent truths without reaching any "brute facts," in modern terminology (Melamed & Lin, 2023).

When further discussing his idea of God as the necessary substance which grounds infinite chains of reasons, Leibniz argues that God must be perfect. For Leibniz, God's act of creation consists in selecting a possible world for existence from amongst all possible worlds—those which do not entail contradictions. Because God is perfect, his choice must not be arbitrary; rather, *he, too must be subject to the PSR*, and his selection must be founded in his ultimate goodness. Thus, the Principle of Perfection is the idea that God chose to create the possible world which is most perfect, meaning that it is both maximally simple and rich in content. (Leibniz, 1989, p.38). This perfection extends to all truths we may uncover, including those regarding the order of the natural world. Further, because God maximized simplicity, Leibniz holds that the regularities we detect in matter around us must not be merely extraneous or accidental to reality's function. Against the occasionalists,[5] Leibniz argues that to attribute motion and change in the material realm to constant miraculous intervention is not an act of piety, but impiety—doing so implies that our world lacks perfection and requires constant assistance from its maker. Rather, Leibniz believes natural science was possible due to the self-sufficiency and order of nature, and he maintains that everything in nature can be explained solely through mechanical explanations, as long as we recognize "that the principles of mechanics themselves depend on metaphysical and, in a sense, moral principles" such as the PSR (Leibniz, 1989, p.245).

When applying the PSR to understand the nature of space, Leibniz notes another useful consequence of this principle. Crafting a *reductio ad absurdum* argument, he holds the PSR to be axiomatic and assumes that space is absolute. In this case, God could have positioned all objects differently relative to absolute space while maintaining their positions relative to one another. Let us suppose, for example, that the totality of objects in space is oriented towards the east; God could have rotated this totality by 180 degrees, orienting it instead towards the west, while maintaining all of the component objects' relative positions. Leibniz holds that "it is impossible there should be a reason" why God would choose one orientation over the other (Leibniz, 1989,

[5] Though diverse in the scope of their claims, the occasionalists held that only God can serve as the efficient cause for changes between states. In this view, it is God's constant intervention—rather than nature's inherent order—which brings about the seemingly natural connections between states both within and between physical and mental substances.

p.325). The choice between orientations thus contradicts the PSR, for it would require God to make an arbitrary decision between two indiscernible options instead of choosing the best in accord with the PoP. As this is impossible, we must eliminate the presupposition which led to this absurdity: absolute space. If space were merely the relations between objects rather than being absolute, there would be no meaning to the thought of orienting all objects in one direction or another, as their interrelations would remain the same. The two orientations mentioned would simply be the same orientation—in short, they would be identical. Reasoning from the PSR in this way results in Leibniz's Principle of the Identity of Indiscernibles (PII), mentioned above. In sum, if we find two conceptual possibilities to be indiscernible such that God could not possess a reason to select among them, these two conceptual possibilities must in fact be the same; the appearance of their difference is due to a faulty presupposition on our part.

Section III: How Metaphysical Principles Relate to Natural Science

Leibniz's metaphysical principles are, of course, not the only foundation upon which one can reason about natural science, and the strengths and weaknesses of these principles relative to others are not the subject of this paper. Rather, Leibniz's principles and their applications serve as examples by which to understand the fruits which metaphysics offers natural science—these principles can be employed to both safeguard the logical coherence of natural science and push scientific inquiries forward by providing methodological guidance.

First, when engaging in natural science, one must be able to justify the assumption that all natural events and phenomena fall under the purview of natural science, as defined in Section II. One means by which to do this is to accept Leibniz's grounding PSR. This is because the PSR assures us that even though we will always be unable to explain reality in its fullness, it is impossible to encounter mere uncaused, brute facts which altogether lack coherent explanations, which would cast doubt on the truth of any attempted theory. If this were not the case, there could be no confidence in the truth entailed by scientific inferences to explain phenomena, for one would be uncertain that all phenomena even possess fitting explanations rather than simply *happening*. In fact, some have even argued that "we cannot know that we have empirical knowledge unless we all have *a priori* knowledge of the PSR" (Koons & Pruss, 2020, p.1079). Thus, presupposing the PSR (or a principle like it) is necessary for scientists because, by assuring us that all facts possess exhaustive explanations, this principle bridges the gap between

the explanatory power of theories and their ability to increase our understanding of the natural world.

Next, to coherently take part in the fundamentally inductive project of natural science, one must address the problem of induction. While often attributed to Hume, Leibniz actually first grasped the fact that the inductive enterprise could not justify itself, for "all the instances confirming a general truth, however numerous they may be, are not sufficient to establish the universal necessity of that same truth" (Leibniz, 1989, p.292). To defend the scientific enterprise from this problem, one could employ Leibniz's arguments based upon the PoP. If one accepts that God created the best possible world, it follows that he has maximized simplicity in nature; thus, nature should behave predictably according to our prior experience of it (Leibniz, 1989). Further, any appearance of irregularity in nature can simply be attributed to an error in our understanding of its logical structure, which we may correct upon learning of it so that our knowledge may further encompass the natural order. Leibniz himself admits that his reasoning provides only a moral certainty in the inductive enterprise, and his attempt to solve the problem of induction was eventually critiqued and overtaken by Kant's approach (Stergiou & Psillos). Yet, his recognition that this problem could not be addressed by science itself, but only through metaphysical reasoning, further demonstrates the necessity of metaphysics to the logical coherence of natural science.

Metaphysical principles are not only necessary to make the nature of scientific inquiry logically coherent. Rather, they can also be used as practical guides in the development and selection of novel theories. One theoretical quandary which possesses significant methodological implications is the problem of empirical underdetermination, which is generally articulated as follows.[6] It is possible for two theoretically incompatible theories to be empirically equivalent, meaning that they differ in their unobservable elements but make identical observable predictions. How can one select the true theory among those which are underdetermined by the data? This problem threatens scientific advancements as potentially arbitrary: if we have no means by which to discern the true theory from among empirically identical options, perhaps we have not previously been approaching truth through science but merely preferencing more

[6] For simplicity, my presentation of this problem assumes a scientific realist perspective, a position which I take Leibniz to hold as well. Even if instrumentalists must also face a form of the problem of empirical underdetermination when determining the more useful of two empirically equivalent theories, they would approach the problem in a different manner than that presented here.

pleasing, useful, or fashionable theories. Yet, a methodological solution is not enough—while some have argued for always selecting the theoretically simpler theory, simplicity could merely be taken as a pragmatic virtue rather than a metaphysically founded indicator of truth (Chakravartty, 2017). Rather, one must forge "a link between […] theoretical virtues and truth" through metaphysical reasoning (Tulodziecki, 2014, p.248).

One metaphysically founded means to approach the problem of empirical underdetermination was employed by Leibniz during the Galileo affair of the 1600s. Contrary to popular understanding, the Church was prepared to accept the Copernican heliocentric hypothesis as merely a useful rather than true instrument. Yet, the Pope argued that the geocentric rather than heliocentric view should be considered true as it could account just as well for the observations explained by heliocentrism while being supported by the Bible. Thus, these theories were empirically underdetermined (Agassi, 1957, p.237-48). To argue in favor of the truth of heliocentrism despite this underdetermination, Leibniz implicitly relies upon his PII and his PoP.

According to the PII, true indiscernibility between the heliocentric and geocentric states of affairs would imply that their seeming ontological difference is simply a chimera—we "suppose the same thing under two names," and we should instead treat them as identical, adopting the view that planetary motion altogether is fictitious (Leibniz, 1989, p.328). Yet, Leibniz takes this view to be absurd—he believes planetary motion to be real and the heliocentric and geocentric realities to not be identical. Thus, by the contrapositive of the PII, these states of affairs must be discernible, meaning that God must have possessed a sufficient reason to select one state over the other. Leibniz argues that, in accord with the PoP, God's reason for selecting heliocentrism over geocentrism is that this arrangement allows him to maximize simplicity "with respect to his means" while maximizing "variety, richness, and abundance […] with respect to his ends or effects" (Leibniz, 1989, p.38). He takes this greater perfection to clearly manifest itself in our formulation of each theory: the geocentric hypothesis requires "multiplying hypotheses or principles" to account for its observations, while the heliocentric hypothesis naturally entails its observations from a few basic assumptions, allowing the arbitrary "labyrinths concerning the stations and retrogrades of the planets [in the geocentric view to] disappear with one mental stroke" (Leibniz, 1989, p.38, 93). The Copernican heliocentric hypothesis is therefore "the truest theory, that is, the most intelligible theory and the only one capable of an explanation for a person of sound reason" because its ability to more simply, harmoniously, and reasonably

explain the fullness of our observations indicates that the heliocentric state of affairs would be divinely preferred (Leibniz, 1989, p.92). Thus, for Leibniz, the notions of truth and intelligibility cannot be torn asunder as the intelligibility of a hypothesis reflects the maximal simplicity and ontological richness woven into the very fabric of nature by God. When faced with two distinct yet empirically underdetermined hypotheses, we are therefore justified in believing the one which is more intelligible.

This approach to the problem of empirical underdetermination is one means to provide a metaphysically grounded procedure for determining the true theory among empirically identical options. Yet, one question remains: what must one do if two theories are both empirically underdetermined *and* equally intelligible? According to Leibniz's PII, these indiscernible theories should be treated as distinct in name only. We must seek out the presupposition which allowed for this chimerical view, eliminate that presupposition, and collapse the theories into an identity. The utility of this method is concretely demonstrated by an example from the work of Albert Einstein.[7]

In his 1905 paper on his induction experiment, Einstein notes that moving a magnet within a conductor while keeping the conductor stationary results in the same electrodynamic phenomenon as the reverse situation, in which the magnet is kept stationary, and the conductor is moved (Spekkens, 2019, p.2). Prior to Einstein's observation and analysis, these situations were considered distinct, for the motion of the objects was thought to differ "relative to the ether." If we consider this scenario taking place in isolation, with only the invisible, undetectable ether as our point of reference, there would be no empirical means to determine whether the conductor or the magnet was moving—even the electric current produced would be the same in both cases. This is an example of underdetermination—both hypotheses entail indistinguishable empirical results. Further, neither option possesses greater intelligibility. Thus, Einstein concluded that the only difference between the two scenarios in question is a confused *conceptual* one—his contemporaries had, in Leibniz's words, "suppose[d] two things indiscernible" by supposing "the same thing under two names," in violation of the PII (Leibniz, 1989, p.328). Rather, Einstein argued, if we attempt to understand these situations while eliminating the "notion of ether or

[7] Though it is not apparent that Einstein explicitly intended to utilize Leibniz's PII, I agree with Robert Spekkens that the principle implicitly used in Einstein's reasoning is nearly identical to that developed by Leibniz, despite subtle differences in expression (Spekkens, 2019, p.1).

absolute rest," we note that the motion of the objects relative to one another remains constant, and we may consider these two situations anew: as one. This conceptual shift away from absolute rest and the ether, and towards the identity of situations with the same relative motion, was foundational in Einstein's ultimate development of the theory of special relativity (Spekkens, 2019, p.2). Thus, it is clear from both this case and that of the Galileo affair that metaphysical principles can serve as logically coherent methodological guides in the practice of natural science, even facilitating the development and acceptance of conceptually groundbreaking ideas like the heliocentric view and the theory of special relativity.

Section IV: Conclusion

Leibniz's Principle of Sufficient Reason, Principle of Perfection, and Principle of the Identity of Indiscernibles underscored all of his philosophical and scientific reasoning. We may put aside potential criticisms of Leibniz's arguments for these principles, for their veracity is not of issue in this paper—rather, their mere existence and practical application indicate fundamental truths about the relationship between metaphysics and natural science. First, these principles can be utilized to ground the inductive, empirical discipline of natural science which seeks to understand the natural world through providing explanatory theories, indicating the fruitfulness of metaphysics for making the enterprise of physics logically coherent. Additionally, Leibniz applied the Principle of Perfection and Principle of the Identity of Indiscernibles to address the theoretical and methodological problem of the empirical underdetermination of scientific theories. This application is significant not only to the Galileo affair, but also to Einstein's reasoning about the obsolescence of the concept of the ether, which ultimately served as a building block in his development of special relativity. It is thus clear that metaphysical principles can also play a crucial role in guiding one's method of theory development and selection, perhaps even more so when one is seeking to make radical advancements on the current scientific paradigm. Therefore, we may thank Leibniz for applying his metaphysical principles to natural science, for he has shown that the latter is unintelligible without the former. Perhaps contemporary scientists would benefit from explicitly recognizing and questioning their own metaphysical presuppositions and following their most promising principles to their logical conclusions—just as Leibniz did.

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