generates—and necessitates—the otherness of nature). Deeper dives into Heisenberg's treatment of these topics alongside those concerning his philosophy of science likewise promise to be fruitful.

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Review of Jeffrey McDonough's *A Miracle Creed: The Principle of Optimality in Leibniz's Physics and Philosophy*

Jeffrey McDonough, *A Miracle Creed: The Principle of Optimality in Leibniz's Physics and Philosophy*. Oxford: Oxford University Press (2022), 234 pp. $74.00 (hardcover).

It is well known that Leibniz is both a bold philosopher and a pioneering scientist, but it is unclear to what extent his philosophy hangs together with his scientific activities. The difficulty of this question arises partly because many of Leibniz's scientific works are scattered in small pieces that tackle only specific technical problems, and it is hard to see how these fragments contribute to a systematic, philosophical understanding of the world like the one described in the *Monadology*. In *A Miracle Creed*, Jeffrey McDonough has successfully identified a leading thread that runs through some of Leibniz's scattered scientific pieces: the principles of optimality. As the name suggests, the principles of optimality state that natural things and events exemplify the best (i.e., optimal) arrangement, and they are obviously rooted in Leibniz's conviction that the actual world is the best of all possible worlds. McDonough's main claim in this book is that the principles of optimality "gained specific content and structure … through Leibniz's efforts to apply it to a series of particular problems in optics, mechanics, and statics between the years 1682 and 1697," and through this more substantiated understanding of

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the best arrangement of the world, "Leibniz's scientific studies lent substantial support to his highly speculative metaphysics" (3).

This book is divided into five chapters. Each chapter is centered around one technical piece and the specific optimality principle used in it. In arranging the chapters, McDonough follows the chronological order in which the pieces are published. Chapter 1 focuses on Leibniz's attempts to derive the fundamental laws of optics first published in *A Unitary Principle of Optics* (1682). Unlike Descartes, who derives the laws of reflection and refraction using the mechanical model of a tennis ball, Leibniz derives them based on the optimality principle of the "easiest" path (12–16). The main idea is that in traveling between two given points, the light ray must follow the path with the least difficulty, which is measured by the product of the length of the path and the resistance of the medium. As McDonough rightly argues, the principle of the easiest path is a teleological principle, because it explains a state of affairs from its optimal outcome, is counterfactually stable, and proceeds from whole to part (20–25). McDonough then argues that Leibniz's use of teleological principles like the principle of the easiest path embodies a kind of thin "lawful teleology" that does not "make essential appeal to substantial forms, non-reductive goods, intentionality, or efficient causal gaps" (35); thus Leibniz's lawful teleology is significantly different from that of Aristotle yet similar to the kind of teleology advocated by some contemporary philosophers. However, although deflating Leibniz's teleology in this way might increase its appeal to contemporary philosophers, it is doubtful whether Leibniz really harbors such a conception of lawful teleology. I will say more about this after summarizing the book. McDonough concludes the chapter by arguing that preestablished harmony, which is generally taken to hold between the mental realm and the physical realm, holds within the mental realm and the physical realm as well (48–58).

Chapter 2 argues that Leibniz's work on bending beams provides a model for his monadological metaphysics. The piece treated here is *New Proofs Concerning the Resistance of Solids* (1684), which builds on Galileo's famous treatment of the breaking of the beam in the *Two New Sciences* (1638). Leibniz's main innovation in this piece consists in applying Galileo's formula to a beam that is bending continuously (63–65). According to McDonough, a continuously bending beam conforms to the principle of optimal form because it optimizes (i.e., minimizes) stress energy. The principle of optimal form will receive more explicit treatment later in the book. McDonough then argues that Leibniz's treatment of bending beams shows how the derivative forces associated with physical bodies may be related to primitive forces associated with monads and, in doing so, provides a model for thinking about the relationship between the bodies of Leibniz's physics and the monads of Leibniz's metaphysics (80–89). The bending beam model also lends support to McDonough's view that monads are spatial per se, as the point forces that make up the beam are just located in the beam (91). The account offered here is intriguing, and the reader might want McDonough to say more on how it affects our understanding of Leibniz's general metaphysics and its development.

Though chapter 3 is about the well-known *Brief Demonstration* (1686), which argues for what is now known as the conservation of kinetic energy (*vis viva*), optics is again the real focus. The discovery of the conservation of *vis viva* is traditionally taken as a turning point in Leibniz's career because it illustrates the contingency of the laws of nature, in turn paving the way for Leibniz's mature view that God freely chooses to create the best of all possible worlds. Against this traditional view, McDonough argues

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that it is Leibniz's successful application of the principle of the easiest path in the late 1670s that convinces him of the contingency of the laws of nature. This chapter is a helpful addition to chapter 1.

The last two chapters are about Leibniz's treatments of the catenary in *A String Bending under Its Own Weight* (1691) and of the brachistochrone in *The Problem of the Brachistochrone* (1696). These two pieces make use of the principle of optimal form. A form is optimal when it minimizes or maximizes the value of a certain quantity both as a whole and in any of its segments. The catenary embodies the optimal form because both a catenary as a whole and any of its segments minimize their potential energy (136–37), and similarly with the brachistochrone, because both a brachistochrone and any of its segments minimize the time of descent (173–76). The main philosophical lesson that McDonough draws from the case of a catenary is that for Leibniz, the actual world is just like a catenary that is optimal both globally and locally. In other words, both the world as a whole and each of its fundamental building blocks (e.g., monads) maximize perfection or "objective goodness" (142–43). Turning to the brachistochrone, McDonough first offers a very historically informed account about how Leibniz's use of optimality principles in tackling physical problems provides the basis for the burgeoning of the calculus of variations and variational principles, especially Maupertuis's principle of least action (176–87). Wrapping up the book, McDonough then offers a defense of the legitimacy of the Leibniz-style optimality principles, arguing that they qualify as the most fundamental laws of nature no less than their efficient counterparts (187–204). Together with chapter 1, this concluding section of the book offers a defense of the kind of thin teleology that is compatible with, yet not reduced to, efficient causal explanation.

This is without doubt an innovative work that will spark many subsequent discussions. And as with any innovative work, there are bound to be points with which one might find fault. Here, for instance, is a more substantial one. McDonough argues that Leibniz has a conception of teleology—named "immanent lawful teleology" by McDonough—that is significantly thinner than the contrasting "thick" teleology of Aristotle. Leibniz's lawful teleology is different from that of Aristotle in that (1) it does not posit substantial forms as the metaphysical ground for final causes, (2) it does not hold that the realization of the goal is inherently good, and (3) it does not take efficient causal explanation to be incomplete (26–28). However, it is doubtful whether there really is a conception of lawful teleology in Leibniz that meets these three criteria. In Leibniz's middle years, he explicitly introduces substantial forms as the metaphysical ground for final causes because "certain things take place in a body which cannot be explained from the necessity of matter alone" (Leibniz 1976, 278). Although substantial forms no longer receive as much emphasis in Leibniz's monadological metaphysics, it is clear that Leibniz still holds that, first, pure mechanism cannot explain most of the natural phenomena, and second, final causes must be grounded in something real, whether substantial forms or the primitive forces of the monads. Thus Leibniz's teleology does not differ all that much from that of Aristotle with respect to (1) and (3), and (2) is no less disputable. As McDonough himself realizes, the optimality principles hold in the current world precisely to realize the most perfection, but he insists that the most perfection is not realized for the physical things' "own actual or perceived good" (27). One possible way to push back against McDonough's view is to say that there is a kind of goodness, commonly referred to as "metaphysical goodness," that applies to physical things as well (Rutherford 1995, 46–49), and the ray

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(for example) takes the easiest path for its own good in the sense of metaphysical goodness. So perhaps Leibniz's teleology is not as thin as McDonough depicts it to be.

Of course, these possible objections do not diminish the overall merits of the book, and one could only admire McDonough's courage and skill in delving into these technical pieces and weaving them into a continuous philosophical narrative. This book should be read by every scholar working in early modern philosophy and science, and it would also appeal to those interested in the interactions between philosophy and science in general.

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