François Duchesneau, *La dynamique de Leibniz*. Mathesis series, edited by Michel Blay and Hourya Sinaceur. Paris: Librairie Philosophique J. Vrin, 1994.

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The significance of Leibniz's work as a physical scientist has long been underestimated or misunderstood. This stems in part from the great success of Newton's physics on the one hand and the influence of Kant's account of scientific knowledge on the other, both of which tend to obscure Leibniz's successes and intentions. It is also due to the unavailability or scholarly neglect of key texts which, if properly assessed, illuminate the work of Leibniz in dynamics. In *La dynamique de Leibniz*, François Duchesneau attempts to give a synoptic view of Leibniz's accomplishments in this field, to do justice to neglected writings, and to show that the course of Leibniz's dynamics offers fresh inspiration for current debates in the philosophy of science and epistemology.

Duchesneau's thesis is that Leibniz's pattern of investigation in physics, the pursuit of a revised program about once a decade, follows directly from his conception of method. For Leibniz, as Duchesneau argues here and at length in the earlier *Leibniz et la méthode de la science* (PUF, 1993), scientific method requires formal analysis of knowledge in the light of high level principles, scrutiny of the patterns of empirical evidence, and the thoughtful integration of principle and fact. The latter will always be possible due to the relation of analogy between the metaphysical, the physical, and the phenomenal, an analogy Leibniz explores in his doctrine of expression. But since what stands in analogy is infinitely complex, and since an analogy is after all an unlikeness as well as a likeness, the scientist must constantly make and revise such integrative hypotheses; as Duchesneau observes, Leibnizian method knocks the *non* off the famous Newtonian dictum: *non fingo hypotheses*.

What then are the stages in the development of Leibniz's physics? Duchesneau, identifying each stage with a set of master texts, counts five. The *Theoria motus abstracti* and *Hypothesis physica nova* (1671) are discussed in chapter one; *De corporum concursu* (1678) (a manuscript newly discovered and edited by Michel Fichant in *La réforme de la dynamique* (Mathesis Series, Vrin, 1994)) is the concern of chapter two; chapter three, which is essentially bipartite, treats the *Phoranomus seu De potentia et legibus naturae* (1689) together with the *Dynamica de potentia et legibus naturae corporae* (1689), and then concludes with a lengthy consideration of the *Specimen dynamicum* (1695); and chapter four considers his later correspondence with Bernoulli, Papin, and De Volder between 1695 and 1713.

The *Theoria motus abstracti* was written in the context of Hobbes's natural philosophy, as well as Descartes' *Principia philosophiae*, the laws of impact for rectilinear collisions that it includes, and the critical response to them given by Wallis, Wren, Huygens in the *Philosophical Transactions* of the Royal Society. Leibniz wrote the *Theoria motus abstracti* as a development of the laws of mechanics in the geometrical manner, an abstract and general deduction organized around the notion of *conatus* borrowed in one sense from Cavalieri's method of indivisibles and in another sense from the *De corpore* of Hobbes: "*Conatus* is to motion as the point is to space, or the unit to infinity; it is in effect the beginning and the end of motion." Various problems concerning *conatus* however remained for Leibniz: how was one *conatus* to be distinguished from and understood in relation to another, and how were they to be related to finite magnitudes like force and mass? Leibniz could not yet fully relate the Cavalierian summation of indivisibles to physical phenomena, and his notion of mass was in any case little more than figured extension. The obvious difficulties in the theory were an unexplored relation to experiment, a lack of internal formal coherence, and a lack of consistency with high level metaphysical principles like the identity of indiscernibles.

Duchesneau contests the claim of Gueroult that the *Hypothesis physica nova* was a sort of appendix containing ad hoc hypotheses departing from the pure deductions of the *Theoria* and intended to save it from the criticism of the Royal Society. Rather, Duchesneau sees the additional text as exemplifying Leibniz's method, that must proceed on the phenomenal as well as the physical and metaphysical levels and must bring them into rational relation, often by means of analogy.

As Duchesneau sums it up, "pour Leibniz, la formulation d'hypothèses est partie intégrante du processus de construction théorique; et ces hypothèses doivent donner lieu à la projection de modèles analogiques à la fois conformes aux algorithmes de type géométrique et aux caractéristiques combinatoires des propriétés physiques qu'il s'agit d'expliquer. Les déficiences de l'*Hypothesis physica nova* ne sauraient discréditer la portée méthodologique de la construction ainsi tentée."

The next stage of Leibniz's reflections on rational mechanics, represented by *De corporum concursu*, comes after his stay in Paris and his tutelage by Huygens, who taught him how to relate geometry to things encountered in experience (like pendula and their trajectories) in a way that far surpasses Descartes. Leibniz however takes up these lessons in a characteristic fashion: the way to construct a physical theory *more geometrico*, he writes, is to apply the principle of sufficient reason in the form of the principle of causality: there must be an equivalence between the total effect and the full cause. (The use of the word equivalence certainly signals the transition from a mathematics of proportions to a mathematics of algebraic equations.) This project becomes in *De corporum concursu* the reconciliation of the conservation of an absolute conserved in mechanical interactions with the lower level rules of impact set out by Huygens and Mariotte, expressed as a system of equations that should exhibit the systematic interrelations of all the initially disparate-seeming cases; in this context he first puts forward his claim that the conserved causal motive force is measured not by mv, but by mv^2. This important development thus springs, as Fichant's commentary and edition make clear, from his conception of method: "Leibniz croit détenir la clé de la conciliation possible entre les lois empiriques et un principe *a priori* de conservation de la quantité de mouvement analogue à celui de Descartes: cette clé serait le principe de l'équivalence de la cause pleine et de l'effet entier." This leads once again to a criticism of Gueroult's interpretation of the genesis of Leibniz's reform of Cartesian dynamics. Duchesneau (and Fichant) argue that it was not made on the basis of merely metaphysical considerations, as Gueroult claims, but springs from Leibniz's happy reconciliation of high level principles with tables of data and systems of equations.

Thus Leibnizian mechanics operates under two constraints. On the one hand it must conform to experimental results, and on the other hand it must carry out an analysis of these results that links them to high level metaphysical principles like that of the equivalence of the total effect and the full cause, and the closely related principle of continuity, which also stems in a sense from the principle of sufficient reason. Much of Leibniz's subsequent reflection at the border between science and metaphysics thus concerned the internal organization of science.

The two treatises from 1689, the *Phoranomus* (a text discussed at length by Robinet, who has for a long time been especially interested in the intellectual fruits of Leibniz's sojourn in Italy) and the *Dynamica de potentia* are attempts by Leibniz to present synthetic deductions of the results attained analytically in the *De corporum concursu*, an exposition in which mechanics is given a canonical form which exhibits the new principle of conservation of mv^2 as the "keystone" of the whole theory. The *Phoranomus*—given in the form of a dialogue and moreover incomplete—is a first draft of the deductive organization of mechanics which the *Dynamica de potentia* develops more fully. The latter text, which Leibniz probably intended as his own counterpart to Newton's *Principia*, was supposed to be published by Bodenhausen in Florence; but Leibniz never completed the text to his own satisfaction, and the project was set aside when Bodenhausen died in 1698. The

Dynamica, published by Gerhardt only in 1860, is thus a full dress systematization of the principles of mechanics built around the notion of *vis insita*. What is most compelling about this text to Duchesneau is, as he says, the juxtaposition and unification of *a posteriori* and *a priori* arguments within the system as a whole. Indeed, Duchesneau is especially interested in the role that truths which are necessary *ex hypothesi* (a kind of hybrid between necessary and contingent truths) play in this "mixed" science.

The first part of this text is devoted to the simple elements of dynamics, abstracted from concrete reality, and is composed as deductions from a set of definitions and a single axiom: "The fact that the same quantity of matter is moved over the same distance in a shorter time, constitutes a greater action." The mathematics he uses in this part includes not only geometry, but the infinitesimal calculus as well, applied in particular to accelerated motion. What results is a derivation of Galilean rules and the principle of the conservation of mv^2 not just from *a priori* principles, but from a mathematical model (which nonetheless is not lacking in empirical import) of "phoronomy," or more precisely a converging series of such models.

In the second part, Leibniz tries to extend this balance between abstract principles and mathematical models of motion by exploring the notion of action contained in each moment of a homogeneous, unconstrained motion. The consideration of accelerated motion leads him to the relation between *conatus* and *impetus*, where the integration of successive *conatus* produces the *impetus*. The principle of the conservation of mv^2 is demonstrated in two ways, one more *a priori* (in terms of the conservation of formal action) and one more *a posteriori* (in terms of the conservation of *vis viva*). Thus in the *Dynamica* Leibniz shows that both kinds of demonstration belong to and can be integrated within the same theoretical framework. Thus Leibniz generates models at once empirical and mathematical, intimately and fruitfully related to each other, and regulated by high level metaphysical principles.

Read in the light of the *Dynamica*, the *Specimen dynamicum* is according to Duchesneau more rigorous and axiomatized but also in a sense more superficial. His characterization of what the *Specimen dynamicum* covers over, the strenuous intellectual effort of Leibnizian science, captures quite well what he understands to be the heart of Leibnizian method: "elle restait au niveau de la symbolisation mathématique et de la projection de modèles *a priori*, plutôt que de s'attaquer de front au rapport entre modèles et entités théoriques et à l'ordre causal sous-jacent aux séries d'états mécaniques représentés par les constructions géométriques et les équations qui s'y greffent." The text, Duchesneau insists, concentrates on architectonic principles and theoretical entities, here multiplied to include *vis activa* *primitiva, vis passiva primitiva, vis activa derivata,* and *vis passiva derivata.*

In the final chapter, which treats the mostly epistolary development of Leibnizian mechanics in the aftermath of the *Specimen dynamicum*, Duchesneau not only gives his fullest articulation of what analysis means in this context but also most openly confronts the *éminence grise* who has shadowed the book all along, Martial Gueroult. In his correspondence with Bernoulli, Papin, De Volder, and Wolff, Leibniz revisits and defends the principles central to his dynamics in analytic fashion: the pendulum has swung back from the synthetic mode of the *Dynamica.* Gueroult views Leibniz's analytic reconstructions here as a falling away from the high moment of the *Specimen dynamicum*; he regards Leibniz's argumentation as an insufficiently justified *a priori* approach which too much resembles that of the Cartesians he opposes, and which moreover requires him to confound the distinction between truths of reason and truths of fact. In Gueroult's view, Leibniz's appeal to metaphysical principles masks his inability to close the gap between experimental results and mathematical theorization.

Clearly, Duchesneau must see this critical view of Gueroult as missing precisely the most important feature of Leibnizian method, since Duchesneau argues here and in his earlier book that Leibniz's use of high level metaphysical principles is just what allows him to move between mathematical models and patterns of empirical evidence, bringing them into a convergent, finally analogical relation. Using his own detailed study of the correspondence with Bernoulli and De Volder along with recent important work by Guillermo Ranea on the correspondence with Papin, Duchesneau formulates several essential features of Leibnizian analysis, including the way in which it moves between real and modal dimensions of the problem at hand, and the way it relates lower level principles to the metaphysical principles as applications (not merely instantiations). Far from being merely equivocal, Duchesneau argues, Leibniz is a philosopher who has successfully mastered the art of metaphor.

My reservation about this book is that it does not go far enough in its exploration of Leibniz's analytic method; perhaps in an effort to be rigorous and avoid speculation, Duchesneau restricts himself to a study of how analysis functions in Leibniz's mechanics even though he observes throughout the book that the process of analysis as a topic must lead one inevitably to epistemological and metaphysical considerations. At the beginning of the final chapter, for instance, he says this about Leibniz's architectonic principles: "Ces principes, et au premier chef la loi de la continuité, fournissent un cadre suffisant d'intelligibilité théorique pour que l'on puisse admettre une anticipation spéculative des lois de la nature." Analysis, I believe, is a process fundamental to all knowledge for Leibniz which indeed reveals much that is fundamental for him about reality itself. Moreover, it involves the notion of intelligibility in a central way, since to analyze something for Leibniz is to search for the conditions of its intelligibility: but this is also to say that intelligibility itself requires philosophical scrutiny.

In sum, the very success of Duchesneau's book leaves the reader with the sense that it points in a direction that has not yet been properly explored. In that direction lies an exploration of Leibniz not just as a physicist, but as a philosopher and indeed as a citizen of the world.

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