François Duchesneau

Leibniz's Dynamics

Origin and Structure of a New Science

Philosophie

Studia Leibnitiana – Sonderhefte | 58

Franz Steiner Verlag

studia leibnitiana sonderhefte

Im Auftrage der Gottfried-Wilhelm-Leibniz-Gesellschaft e.V.
herausgegeben von Herbert Breger, Michael Kempe,
Wenchao Li (verantwortlich) und Pauline Phemister

In Verbindung mit Maria Rosa Antognazza †, Stefano di Bella, François Duchesneau, Michel Fichant, Emily R. Grosholz, Martina Hartmann, Nicholas Jolley, Eberhard Knobloch, Massimo Mugnai, Arnaud Pelletier, Nicholas Rescher und Catherine Wilson

Band 58

https://www.steiner-verlag.de/brand/Studia-Leibnitiana

Leibniz's Dynamics

Origin and Structure of a New Science

François Duchesneau

Franz Steiner Verlag

Bibliografische Information der Deutschen Nationalbibliothek:
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über dnb.d-nb.de abrufbar.

www.steiner-verlag.de
Layout und Herstellung durch den Verlag
Satz: DTP + TEXT Eva Burri, Stuttgart
Druck: Beltz Grafische Betriebe, Bad Langensalza
Gedruckt auf säurefreiem, alterungsbeständigem Papier.
Printed in Germany.
ISBN 978-3-515-13520-7 (Print)
ISBN 978-3-515-13526-9 (E-Book)
https://doi.org/10.25162/9783515135269

Acknowledgments

This book is a second edition of *La Dynamique de Leibniz* (Paris: Vrin, 1994). It includes several modifications brought to the original version and takes account of various advances in scholarship concerning Leibniz's philosophy of nature in the recent years. It is offerred to the readers in English, thanks to the talent and dedication of Paul Jackanich who completed most of the translations.

Over the years, my reconstitution and interpretation of Leibniz's dynamics has benefited from the exchanges I had with Leibnizian scholars and friends on this precise topic. I express my gratitude to all of them, but especially to Michel Fichant, Richard Arthur, Daniel Garber, Anne-Lise Rey, Laurence Bouquiaux and Christian Leduc.

What is most challenging for whoever explores the essence of Leibniz's science is that, notwithstanding the best efforts deployed, there is no chance of reaching a final and definite view on the contents of it, because Leibniz himself never put a stop to his enquiries, nor ceased to work out improved versions of his developing theses from various perspectives. This is especially true about the dynamics, whose major piece, the 1689 *Dynamica* went through many rewritings and remained uncompleted in light of Leibniz's own objectives.

This shall be my excuse for suggesting that this book of mine be considered as a mere attempt at providing a provisional synthesis on what formed the principal contribution of Leibniz to natural philosophy, in his own time and for his posterity.

Table of Contents

Introduction

One cannot deny the significance of the contributions that Gottfried Wilhelm Leibniz (1646–1716) made to science in his day. Nor can one deny their impact on posterity. Even in an era dominated by Newtonianism, the discovery of infinitesimal calculus and the invention of dynamics, to give two examples, certainly could not have been overlooked. The influence of Leibnizian science was profoundly felt throughout the 18th and 19th centuries, even when Newton's model reigned supreme. Following a complete overhaul of physics in the beginning of the 20th century and the gradual displacement of the Newtonian model, Leibniz appeared more and more as someone offering an original and, in many ways, relevant conception of the scientific method, as someone whose scientific theories had played a major role in the history of science.

Contemporary scholars have indeed worked on reconciling certain, more recent theses with earlier formulations that can be traced back to Leibniz, a precursor of the Enlightenment. As such, they have drawn diachronic comparisons on themes like relativist analyses of motion, the rational ideality found within the foundations of the cosmological categories of time and space, the need for a concept of force for theorizing energy and field effects, and the role of principles of conservation in deciding upon explanatory models. All of these themes might serve as subjects of analysis and comparison, so long as we avoid the risks of altering their contents or introducing anachronisms. All of these also possess references and convergent meanings that today's science shares with Leibniz's, which clearly distinguished itself in its time from the argumentative style and the theses developed by Newton and the Newtonians. Herbert Breger rightly points out that the reasons why scientific Leibnizianism ceded its place to Newtonian physics are the very same ones that have, in our time, renewed interest in Leibniz's approach to science.[1] The theoretical Newtonian model would present itself as a strictly mathematical system, "deduced from phenomena" and designed to account for a vast host of empirical problems. By contrast, Leibniz endeavoured to study the "metaphysical" foundations of physics, and thereby the development of principles of explanation and analysis that would allow for approaching empirical problems in

1 "Symmetry in Leibnizian Physics," in Breger (2016), 13–27.

a way consistent with the demands of theoretical sufficient reasons. This explanatory approach relies on architectonic principles and hypothetical-deductive inferences for analyzing phenomena. Such is the specific content of the Leibnizian style, which not only demonstrates its relationship with contemporary methodology, but also underscores the historical uniqueness of its concepts, theories and models for representing phenomena.

Ultimately, the recent interest of scientists and philosophers in Leibniz's work seems to be epistemological in nature more than anything else. The way in which Leibnizian theories are modeled is intriguing and can offer insight into fundamentals of the philosophy of science such as the formulation of models for analyzing phenomena, the demands of causal explanation, the relativity of concepts of sufficient reason that represent the empirical world, and the invention and justification of theories in conformity with architectonic principles.

We have elected to focus here on the origins and structure of the most elaborate theoretical body in Leibniz's science, the dynamics. Leibniz himself planed for the dynamics to become the heart of his physics. The dynamics unfolds against a historical backdrop. Its starting point is a particular theory of the combination of motions placed within the framework of a mechanistically conceived natural philosophy. Even before his stay in Paris (1672–1676), Leibniz had elaborated an abstract mechanics in the *Theoria motus abstracti* (1671), whose counterpart in the *Hypothesis physica nova* (1671) consisted of a hypothetical physical theory involving material structures, which were themselves the products of combinations of motions. Faced with the inconsistency of this first synthesis, Leibniz must then take into account the empirical laws of impact as established, from 1668 on, by Huygens, Wallis, Wren and Mariotte. At the end of his stay in Paris, he sets out to reconcile these laws as well as the theorems concerning percussive forces with the help of the principle of conservation of quantity of motion for which Descartes had provided the formula in 1644. Following a remarkable demonstration of combinatorial analysis and with the help of *sui generis* methodological rules, Leibniz thus succeeds in formulating a new principle of conservation. As the work of Michel Fichant has taught us,[2] this systematic reform occurs at the beginning of 1678. But public announcements of the discovery do not emerge until 1686 with the publication of the *Brevis demonstratio erroris memorabilis Cartesii*. A host of arguments and texts, some published and others not, will provide the foundations of a complicated theoretical structure for this new science that will soon blossom. The *Dynamica de potentia* (1689–1690), the *Specimen dynamicum* (1695), and the later *Essay de dynamique* (c. 1700) represent significant steps of this process. Some famous controversies and correspondences on the demonstrative arguments of the theory, particularly on the so-called *a priori* approach, yield a complex and disparate body of work, across which

2 Fichant (1990); Fichant, Introduction, in Leibniz (1994), 9–65.

one of the major discoveries of modern science takes shape. Focusing on these significant texts, and with a view to the series of arguments that they contain, our objective will be to analyze the methodological procedures and methods of theorization at work in what constitutes Leibniz's dynamics.

Certain difficulties beset this type of research. As a whole, the scientific work of Leibniz has suffered from several partial interpretations or distortions. The works that the librarian of Hanover published during his lifetime only represented a small part of his corpus; these often included allusive texts that only indirectly reflected the magnitude of fully completed analyses. The publication of manuscripts has been spaced out up until our own time and still continues; hence, all accounts, including those of the recent past, were doomed to produce some necessarily truncated picture of a multifaceted subject. Responding to this problem, Michel Fichant worked for several years to reconstruct the text of the *De corporum concursu* (1678) and provide us with an edition (Leibniz 1994). This very important draft contains the birth of the reformed mechanics; it reveals how Leibniz perceived the necessity of reforming Cartesian mechanics and substituting the principle of conservation of quantity of motion (measured by the product *mv*) with a new principle of conservation that would account for living force (measured by the product mv^2). Leibniz implements this reform with the help of methodological and epistemological tools that none of the great interpreters of his work before Fichant had identified as reaching this stage of development. Such a lacuna proves significant. However, in the majority of cases, the difficulty of constructing a representation of Leibniz's science reveals itself in a more subtle way. The texts are numerous, often fragmented, and sometimes divergent, addressing diverse questions. The *sui generis* coherence of the whole tends to escape us. It is easy, if not inevitable, to stray from a sufficiently faithful analysis for an arbitrary reconstruction of a larger than life Leibnizian model.

Several important works have directly contributed to establishing a more adequate vision of Leibniz's science and the philosophy of science that accompanies and underpins it. But this is above all true for studies focusing on the contributions of Leibniz to the formal sciences, such as the analyses of Couturat, Kauppi, Ishiguro, Burkhardt, several others on the logic, and the analyses of Hofmann, Belaval, Knobloch, Serfati, and their present successors on Leibniz's mathematics.[3]

Leibniz's epistemology of the natural sciences is a different story, notably with regard to the mechanics. Indeed, numerous commentators have taken an interest in this sort of research on Leibniz, but in our view, only one remarkable work on the dynamics proper had been published, Martial Gueroult's *Leibniz. Dynamique et métaphysique* (Gueroult 1967; first edition: 1934). Gueroult placed the neo-Kantian and positivist interpreters of Leibniz's science back to back. He established the particular coherence

3 All these works are cited in the bibliography.

of a scientific approach that aimed to construct a sufficient and autonomous representation of the phenomenal order by combining inductive and deductive methods; he showed at the same time how this explanatory construction justified itself within the metaphysical context that defines the monadological system, and how it required theoretical foundations more profound than the laws governing the interaction of phenomena. The picture that Gueroult paints is remarkable for a host of reasons, and far surpasses in depth and scope all of the partial reconstructions of the dynamics with which interpreters had busied themselves.

We must however push back against the master on certain points. Gueroult approaches all of the Leibnizian texts known to him as if they ought to form so to speak a coherent, atemporal whole. But the changes that Leibniz's work underwent are significant and must necessarily be taken into account. The lack of appreciation for the evolutive character of Leibniz's scientific thinking is apparent, first, in the absence of any reference to the methodological styles that were successively developed in the texts that prepared the way for, and then dedicated themselves to the dynamics. Indeed, Gueroult never identified the seminal text of the reform, *De corporum concursu*; but more generally, all of the Leibnizian methodology lay hidden in the shadow of this brilliant analysis of the normative structure of the dynamics. From this approach there followed a categorial denunciation of the so-called *a priori* method for demonstrating the principles of conservation of living force and formal action, and by contrast, an equally categorical prioritization of the so-called *a posteriori* method. In this regard, it seemed that Gueroult understated the complexity of the theoretical constructions and relied on the surreptitious resurgence of a model dominated by the Newtonian paradigm. Comprising knowledge procedures capable of founding and justifying dynamics as a science, it was still a Kantian epistemological model that served as a point of reference and allowed the originality of the Leibnizian position to be inferred. Finally, it was difficult to imagine, beyond the limits of the dynamics, how Leibniz could have conceived of the structure of a science of complex phenomena. The reconstituted coherence of Leibniz's mechanical system obscured in a sense the broad spectrum of possible theoretical models, which owed to the degree of complexity of the phenomena being considered. If Gueroult gave expression to the "metaphysical form" of the dynamics, he sidestepped every analysis of the methodological profile of Leibniz's science. In conformity with a post-Kantian tendency, the conception of the system took precedence over the conception of the method when it came to framing the argumentative structure of Leibniz's physics.

By contrast, a number of more recent studies on Leibniz's science outline the first steps of an approach similar to the one that we intend to adopt.[4] These studies will

4 Cf. Bouquiaux (1994); Fichant (1998); Garber (2009); Tho (2017); Arthur (2018); Garber and Tho (2018).

buttress the establishment of a framework of analysis that we regard as more suitable for representing the epistemological interpretation of Leibniz's science. We shall therefore not inscribe *Prolem sine matre creatam* upon the frontispiece of this work, as Montesquieu did for his *L'Esprit des Lois*. In the contemporary context of the history and philosophy of science, we may content ourselves with being well-informed, critical successors, apt to explore some new avenue of research that might prove original and promising. Our means are no doubt furnished by the riches accumulated by our predecessors, distant and close. Such a debt merits recognition.

In another work on *Leibniz et la méthode de la science*,[5] I drew from the analysis of the dynamics to bring to light some more general perspectives relating to Leibnizian science as a whole. I focused on the programmatic aspects of Leibniz's conception of science, and examined the methodological considerations that it furnished philosophical analysis. I therefore addressed epistemological topics such as the creation of an innovative methodology that proves to be not only combinatorial and analytic in nature but also rational and empirical, the relationship between the various categories of truth, the fundamental and complex role of conditionally necessary truths, the structure and function of scientific hypotheses the model for which is both analytic and heuristic, and finally, the specific role assigned to architectonic principles, namely finality, the identity of indiscernibles, and continuity.

One cannot however deny that the invention of the dynamics dictates all reflection on the scientific methodology of Leibniz. The true method develops over the course of his scientific labors, and reveals itself through the demands of the science's development. This is true of the Leibnizian method both in terms of its evolution and its content. Our plan here is therefore to locate the genesis of the dynamics as science, and to retrace the main steps of the argumentative structure that emerges and unfolds across Leibniz's works. The chapters that we shall devote to this scientific project include the genesis of the reformed mechanics, the structure of the theoretical corpus of the dynamics, and the meaning that we must attribute to one of the most problematic methodological aspects of such a construction, the *a priori* analytic model.

5 Duchesneau (1993); Duchesneau (2022).

Chapter I
The Initial Scientific Project

Commentators agree in general that Leibniz's philosophical thought process undergoes a significant transformation during his stay in Paris (1672–1676). Examining the philosopher's career, is the Parisian phase not characterized by the influence of the novel mathematics and experimental physics to which his new mentor, Christiaan Huygens, exposed him? The fruits of this crucial period are well known: the infinitesimal calculus on the one hand, and on the other, the first critical reflections on natural philosophy that will lead to the reformed mechanics (1678). Indeed, these discoveries will not see the light of day until later on, but they had already begun to transform the orientation of Leibniz's research when he undertook his new librarian duties in Hanover. There is every reason to believe that this revised scientific project guides the establishment of his metaphysical system, just as it directs Leibniz's interests in empirical investigations up until the publication itself of the principles discovered in the period of 1685–1700. But what then of the first philosophy of Leibniz? Is it relegated to simply being an object of historical curiosity? Does it have no relation to the philosophy of science whose components we wish to identify?[1]

The period of the initial scientific project begins with the *Dissertatio de arte combinatoria* (1666) and ends in 1671 with the publication of two treatises, *Theoria motus abstracti* and *Theoria motus concreti* (or *Hypothesis physica nova*), respectively dedicated to the Académie des Sciences of Paris and to the Royal Society of London. But Leibniz will never entirely repudiate the contributions of this period; instead, he will emphasize the inherent limits of the algorithms used in the *Theoria motus abstracti* and the errors that it might have produced in the establishment of an abstract mechanics. Consequently, the arguments of the *Hypothesis physica nova* seem incomplete, but might suffice as a theoretical framework that prepares the way for research that will respond to the provisional and revisable systematization of that science. After the Parisian period, Leibniz eloquently attests to this in the letter that he addresses to Honoré Fabri in 1676:

1 On these issues, we can rely on Beeley (1996).

> You see what I had undertaken when I founded my *Physical Hypothesis*, in which I only scratched the surface of the subject, but it nevertheless seems that my work was useful. For I called the attention of men to a new, and if I dare say, truer way of reasoning about nature. If I, young man that I was, practically a novice in these matters when I wrote about them, was too daring, I would ask that you hold onto, not my example, but my design, which others endowed with greater intelligence and experience might pursue with superior success. There is however no reason to be dissuaded by the outcome of a first attempt, and I do not doubt that one day I shall be able to say things more refined than even now, but I save that for another time, since deeper investigations are in order. (A II 1^2 443–44)

One must surely disabuse oneself of the impression of deficiency that commentators often highlight when examining these texts, and instead keep an eye out for the determinative foundations and beginnings of a definitive systematization. In the *Specimen dynamicum* (1695), Leibniz will indeed emphasize the deficiencies of the first mechanics that are attributable to the *Theoria motus abstracti*, but also the vision of a more "systematic" explanation of things that further research would address.[2]

If Leibniz goes beyond his initial perspectives and theses, then it is always with relative methodological continuity. Regarding the theses of *De arte combinatoria*, this is no doubt what the interpreters of Leibniz's logic tend to underscore.[3] With respect to the texts on physics, one has often fallen victim to the critical rigor that comes with retrospectively judging from the more advanced theses of the dynamics. Thus, Gueroult easily exposes the lacunae of the first mechanics in light of the remarkably well articulated relations between the metaphysics and mechanics of *vis viva* that one finds in the later phase of scientific completion.[4] This recurring rubric is far too restrictive however, for it undoubtedly overlooks the characteristics of the research program as they are formulated in 1670–1671, when the abstract and concrete theories of motion come together in a remarkable way. Furthermore, Gueroult does not sense the profound affinity that the scientific project has with empiricist methodology, not only as it was conceived of by thinkers like Hobbes, but also as what Leibniz describes in a somewhat general manner so as to include the experimental research of the Royal So-

2 Cf. *Specimen dynamicum* (1695), GM VI 240–41, L 440 (modified): "When I was still a youth and followed Democritus, along with his disciples in this matter, Gassendi and Descartes, who held that the nature of a body consists in inert mass alone, I brought out a small book entitled *A Physical Hypothesis*, in which I expounded a theory of motion that both abstracted from the system and blended with the system (*systemati concretam*). This writing seems to have pleased many distinguished men far more than its mediocrity deserved. [...] Later, however, after I had examined everything more thoroughly, I saw what the systematic explanation of things consists in and discovered that my earlier hypothesis about the definition of body was incomplete."

3 Cf. Couturat (1969), 33–50; Kauppi (1960), 129–144; Ishiguro (1990), 44–60.

4 Gueroult (1967), 8–20.

ciety's *virtuosi*.[5] One of the best general representations of Leibniz's first philosophy remains undoubtedly Hannequin's.[6] However, taking specific interest in the rational analysis that Leibniz develops for a metaphysics of motion (*motus*) and thought (*cogitatio*), Hannequin tends not to grasp the overlap between the theory of knowledge and the scientific methodology that one finds in the theses of this proto-Leibnizian metaphysics. Likewise, Kabitz's[7] work underestimates the specific interest that the *Hypothesis physica nova* presents, as well as Leibniz's overall project for advancing the methodology of empirical science. For their part, the more recent studies of Konrad Moll attempt to systematize the complex influences that Weigel and Gassendi had on the establishment of the first philosophy,[8] but Moll's reconstructions are too unilateral and not sufficiently focused on the epistemological profile of the works that crown the youthful period.

Given the current state of affairs, it seems that one may benefit from further investigating the elements of the philosophy of science that can be found in the treaties of 1671, as well as in the texts that prepare, prefigure and complete them.

1. Analyzing Reality in Terms of Motion

In his study on "La première philosophie de Leibniz",[9] Hannequin traced the development of Leibniz's views on the theory of matter back to his time at the University of Leipzig, when he rejected the substantial forms of the Scholastics in favor of a corpuscular theory of the Gassendi variety.[10] He notes in particular how Leibniz increasingly criticized the architectonic notions of theories of this kind, and therefore sensed the need for a causal reason for motion that differs from reality as extension and shape, even though motion furnishes the key for generating physical properties of size, extension and shape. Thus, in 1669 in the *Confessio naturæ contra atheistas*, Leibniz succeeds

5 Loemker (1973), 248–275.
6 Hannequin (1908), II, 17–226.
7 Kabitz (1909).
8 Moll (1978–1982).
9 Hannequin (1908), II, 17–226.
10 Cf. for instance, the letter to Remond on 10 January 1714, GP III 606; L 654–55: "I discovered Aristotle as a boy, and was not even discouraged by the Scholastics; even now I do not regret this. But then Plato too, and Plotinus, gave me some satisfaction, not to mention other ancient thinkers whom I later consulted. After freeing myself from the trivial schools, I fell upon the Moderns, and I recall walking in a grove on the outskirts of Leipzig called Rosental, at the age of fifteen, and deliberating whether to hold onto substantial forms or not. Mechanism finally prevailed and led me to apply myself to mathematics. It is true that I did not penetrate its depths until after some conversations with Mr. Huygens in Paris. But when I looked for the ultimate reasons for mechanism, and even for the laws of motions, I was greatly surprised to see that they could not be found in mathematics, but that I should have to return to metaphysics."

in justifying the foundations of physical properties via the activity of a *mens*, which itself is conceived of in terms of the analogical division between finite minds and the infinite, guiding Intelligence of the universe. From then on, and following the letters to Jacob Thomasius in 1669–71, in which he attempts to forcibly reconcile his mechanical physical theory with Aristotelianism, Leibniz develops a theory of *conatus* inspired by Hobbes, which will serve as the foundation of the *Theoria motus abstracti* (1671). The *Hypothesis physica nova* intercedes to secure the connection between the theory of *conatus* and auxiliary hypotheses subordinate to the metaphysics of the *mens*, which maintain the fragile harmony of the theoretical model. Daniel Garber, for his part, analyzes the same sequences in a somewhat different fashion.[11] According to his interpretation, in the period between 1668 and 1670, Leibniz invokes notions of God and continuous creation to provide a substantial foundation for the motion of bodies, beyond their association with finite spirits. And during the period of 1670–1672, Leibniz advances, as the *Theoria motus abstracti* attests, a veritable "mentalization of bodies", a thesis according to which every corporeal entity is likened with a *mens momentanea*.[12] To be sure, these interpretations are coherent and instructive, but one must take stock of the epistemological elements that they ignore or underestimate.

One of the most significant texts in this regard is the *Nova methodus discendæ docendæque jurisprudentiæ* (1667). There one finds methodological assertions that are essential for elaborating upon natural science. Leibniz rejects here the Cartesian precept of evidence in favor of two criteria that seem to him capable of avoiding every possible deception that might arise when framing concepts and judgements: "Analysis, or the art of judgement, seems to me to be almost entirely accomplished by the following rules: 1) never accept a single word that is not explained; 2) never accept a single proposition if it is not proven." (A VI 1 279) These two criteria govern analysis. Four disciplines provide the principles that permit the faculties of knowledge to be orientated toward the appropriate *habitus mentis*, once the propositional character of the mind's operations has been accepted. Mnemonics depends on the signs that one must use to determine the relations of comparison or connection without which the working of the mind is impossible: Leibniz seems to borrow his notion of signs from Hobbes' *De corpore* (1655).[13] The goal of topos theory, or the art of inventing by associating *topoi* or transcendental relations such as totality, causality, matter and similarity, is to govern the combination of terms, represented by signs, from which propositions are formed.

11 Garber (1982), 160–184.

12 Cf. *Theoria motus abstracti*, § 17, A VI 2 266; letter to Oldenburg on 11 March 1671, A II 1^2 147: "[…] every body is an instantaneous mind (*mentem momentaneam*), and thus without consciousness, sense and memory." Regarding this mentalization of the body, cf. Garber (1982), 171–72: "*Leibniz […] has put motion, now conatus, into the bodies themselves*. But since mere extended things cannot properly speaking have conatus or motion, and since the essential property of body *is* motion, the bodies must not be mere extended things: *they must be minds of a sort*."

13 Cf. Hobbes, *De Corpore*, I, ii, §§ 4–5, OL I 14–15; EW I 16–17.

Analysis is itself the art of judgement, and its goal is to arrange terms in such a way as to produce scientific propositions. Methodology, for its part, is the art of assembling propositions either in a natural way, that is, by order of demonstrative dependency, or in a sequential way, when one is unable to conceive of absolute demonstrative dependency and must content oneself with an order that seeks to grant verisimilitude. The logical classification of propositions should be conducted by regarding the terms in question as the material of relational propositions. This idea was determinative in *De arte combinatoria* (1666),[14] but Leibniz makes use of it here to account for the architectonics of scientific understanding.

Referring to Francis Bacon's *De augmentis scientiarum* and *Novum organum*, Leibniz develops a three-level conception of science that would focus on "histories, observations and theorems." (A VI 1 285)[15] History is situated on the level of describing facts and is expressed through singular propositions such as: *Francis Hall (Franciscus Linus) fixed, without any visible connection points, an iron marble at the center of a glass sphere supposedly filled with water* – which he could have accomplished with a magnet and by pouring two different liquids, immiscible but indistinguishable to the eyes, into the sphere. History can include describing fictive facts such as when one is confronted with the assertion: *A magnet holds Mohamed's casket suspended in the sky above Mecca*. Observations are formulated via contingent and universal propositions, and follow from an induction based on singular propositions, for example: *Every magnet attracts iron*. There remains the case of theorems, or maxims, which correspond to science per se. These are composed of necessary and universal propositions, for example: *Everything that is moved, is moved by another thing*, or *If the magnet attracts iron, there must be bodily effluxes transferred from the magnet to the body*. Following a Baconian sort of conception, Leibniz conceives of science in a general sense as a controlled combination of these three propositional tiers, which implies that the constructive materials, i. e., the terms, are located at the source of various nested propositional connections.

More precisely, Leibniz outlines a classification of simple terms that make up complex terms, a classification that is ultimately dependent on the empirical order. Simple terms present themselves immediately to sensory perception, and comprise sensory qualities as such, which are mediately perceived via bodily organs, as well as powers that the mind perceives within itself. In 1667, Leibniz identifies the latter with thinking and causality – during his revisions in 1697–1700, he will speak of perceptivity and activity.[16] Mediated by sensation, the being represented is understood as referring either to the object that is directly perceived or inferred from another perception. Its essence

14 Cf. for instance Couturat (1967), 35.

15 Bacon's three-level conception of scientific propositions is in particular analyzed in Pérez-Ramos (1988), 239–69.

16 A VI 1 286, z.2–8 D: "By the mind, only two things are perceived: perceptivity (that is the power to perceive) and activity, that is the power to act."

is comprised of qualities that are instantiated together for sensory apprehension. Its existence corresponds to the possibility of being an object of sensation. Recognizing several beings together gives rise to relations of co-imagination or co-essence (sameness, difference, similarity, dissimilarity, opposite, genus, species, universal, singular) and those of co-sensibility or co-existence (whole, part, order, one, several, necessary, contingent, together, cause, etc.). Regarding the qualities arrived at through the mediation of bodily organs, Leibniz conceives of them as either specific or shared. But he distances himself considerably from the Aristotelian view by identifying shared qualities only with number and extension; the abstract representation of these qualities in accordance with their various modes yields the object of arithmetic on the one hand, and that of geometry on the other. And he adds: "Everything that possesses another sensory quality beyond extension and number is called a *body*. Everything that does not possess it is called *vacuum*. It is here that *physics* comes into being." (A VI 1 287) Among these qualities, motion perceived through the medium of touch plays a fundamental role insofar as all other qualities can be analyzed into subtle motions once their extension is determined. In order to implement such an analysis, one requires facts of experience that are capable of furnishing the most adequate model within the framework of general extensive determinations: "Touch also has special qualities: solidity, fluidity, tenacity (resistance), softness, etc. whose history must be very diligently compiled like that of light, colors, sounds, smells, and flavors, such that one can more easily establish their cause by matter and motion." (A VI 1 287–88)

The revision notes of the 1697–1700 period suggest certain modifications regarding the typology of common qualities, and regarding the concepts on which theorization (the third level of the science) depends. Number belongs to internal sensation just as much as it belongs to various external sensations. The modes that characterize it give rise to an algorithmic theory that directly bears on how the contents of perception are combined when they are transposed into logical combinations; what is more, this logical transposition furnishes "metaphysical theorems" capable of shedding light on other fields of truths. Likewise, the category of causality or mental activity gives rise to a positive concept of *conatus* that, transposed within the study of compound bodies, yields a concept of motive force and thereby paves the way for establishing the mechanics. Arithmetic engenders geometry by adding *situs* to number: *situs* is the co-existent order that introduces quality within quantity. Thus, in these belated notes one finds the idea that the reflexive perception of the mind yields concepts essential to theorizing nature. The categories generated by external sensory experience would therefore need to be formulated in consequence of the powers of the mind and the concepts that reveal themselves to the apperception of the knowing subject. To be sure, the doctrine of 1667 does not surpass the limits of what is essentially derived from sensory qualities, even if the category of causality presupposes an analogous shift from reflexive to perceptive experience. Leibniz nonetheless distinguishes between abstract and concrete philosophy when it comes to these qualities. It seems that abstract philosophy proceeds via *a priori* constructions based on simple terms; concrete philosophy, by contrast, proceeds via the analysis of complex subjects, or phenomenal realities, in terms of primordial qualities and therefore via the combination of simple terms. "Here one is doing nothing more than historically [i. e., empirically] identifying the qualities of things; and one demonstrates nothing new, but simply subsumes what was previously demonstrated in abstract philosophy". (A VI 1 288) In a way similar to Hobbes', in 1667 Leibniz conceives of physics as the study of complex motions within an extended space that can be divided by number relations. At the same time, he senses that the empirical analysis of sensory qualities, and of the subtle motions that they represent, can, by means of abstract signs referring to simple mathematically expressed terms, provide an opportunity for subsuming everything under universal and necessary propositions. Already, this thesis deviates away from the Gassendian corpuscular hypothesis, and toward the geometric representation of observable motions and subtle motions – this being the only conceptually recommendable means of analyzing phenomena. It is particularly apparent that the solidity of bodies, i. e., their antitypy or impenetrability, temporarily ceases to appear as a positive quality since it ought to be reduced to subtle motions that suffice for producing such an effect. The notes of 1697–1700 will reestablish resistance, like extension, as being at the very least an essential category of the phenomenal universe. But only then will the concept of *vis viva* come to justify a typology of derivative active and passive forces. The model that Leibniz initially relied on to account for material essences was one that abstractly represented these essences in terms of subtle motions.

This strategy goes hand in hand with the critique of atomism, as the fragment *Confessio naturæ contra atheistas* (1668–1669) attests. (A VI 1 489–93) In keeping with the criteria of the Moderns, one relies on the primary qualities of size, shape and motion in order to explain phenomena. This involves determining if one can thereby account for phenomena without presupposing incorporeal causes. But the primary qualities of phenomenal realities cannot be derived from the definition of body as that which "exists in space". Most of all, the reason for one shape or size cannot derive from this postulation of the nature of bodies; likewise, bodies are movable in virtue of their existence in space, but the reason for motion cannot, it seems, derive from the bodies themselves. From this critical approach, Hannequin concluded that Leibniz relies on what is undoubtedly a conceptual analysis that could be situated within the trajectory of a pronounced rationalism.[17] Indeed, this may not be the case. The concepts in question are simple terms that represent shared sensory qualities in their immediacy. If the analysis works this way, it is because it does not seem to account for the sensible world beyond its phenomenal shapes and motions. The solution that Leibniz favors differs from a phenomenalization of the sensory universe analogous to what one finds in

17 Hannequin (1908), II, 34–39.

Hobbes for example. Leibniz's solution deviates theoretically from the latter owing to its reliance on the *mens infinita* as the appropriate sufficient reason for the foundation of the phenomenal universe. Integrating this theoretical sufficient reason into a geometry of concrete motions to justify its specific order and qualitative determinations constitutes the anti-Hobbesian project of Leibniz according to the *Confessio*. Nevertheless, we certainly do not wish to deny that the orientation itself of the analysis of phenomena conforms to an empiricist approach similar to Hobbes' own in *De corpore*.

The critique of the reductionist viewpoint falls within this approach. It relates to the problem of solidity and its three effects, resistance, cohesion and reflection, which bodily displacements and impacts reveal. Can one adequately account for this basic physical quality in terms of the shapes, magnitudes and motions of the implicated bodies? The strategy of Leibniz consists in pointing to the limits of the best hypothesis, that of Hobbes, for whom the resistance of bodies and the maintenance of their cohesion via an endogenous reaction to exogenous percussions owe to the compensatory effects of the *conatus*.[18] This might apply to perpendicular impacts that cause imperceptible compensatory motions on the affected surface. But what of oblique impacts that cause reflections? In the span of an instant, the reacting motion dissipates without contributing either to the cohesion or the reverberation. One might then rely on more specific models, devised as simple modalities of the corpuscular hypothesis of the atomists. The elementary parts would produce solidity by various kinds of specific shapes, hooks, barbs, rings, etc. by which they would attach to one another. Leibniz asserts from the outset that the question thus concerns the cohesion of the parts inherent to these features themselves. The inquiry into the sufficient reason of solidity would thereby be inscribed within an infinite process of analysis. Modern philosophers such as Gassendi can only find refuge in atoms that are by definition indivisible. But then the explanation is founded on no other sufficient reason for the solidity of atoms than the free will of God. And, since the concept itself of matter offers no other sufficient reason for the shape, magnitude and motion of any part whatsoever, one must postulate that this infinite incorporeal cause, the origin of the *firmitas*, also imposes a design that is necessary for determining the modes or properties of natural realities; and, since these determinations form a combined whole, this involves a comprehensive and complete structural design. Such is the inspiration behind this metaphysical argument:

> It is impossible to understand the reason why this incorporeal being chooses this size, shape, or motion rather than another, unless it is intelligent and wise in virtue of the beauty of things, and powerful in virtue of their obedience to its will. Such a being would therefore be the Mind governing the entire universe, that is, God. (A VI 1 492)

18 Hobbes, *De corpore*, III, xv, § 2, and xxii, § 18–19, OL I 178–79. 283–84; EW I 211, 347–48.

This is clearly a departure from the path embarked upon by Hobbes, who sought to explain solidity in physical terms. Even if this way of theorizing in terms of motion obliges us to suppose that such and such motion extrinsically acts upon the material parts, and thus prevents us from accessing the ultimate physical causes of things, Leibniz seems to venture in this direction in his quest for a sufficient reason for basic phenomena.

It is in this context that one finds the suggestions for amending Hobbes' system and for harmonizing the method of the new physics with a metaphysics of nature that responds to a so-called Aristotelian framework. Such are the goals that one can infer from the letter to Hobbes on 13/22 July 1670, (A II 1^2 90–94) and from the letters to Jacob Thomasius on 26 September/6 October 1668 and 20/30 April 1669. (A II 1^2 17–19, 23–38)

In the first place, Leibniz is interested in the "general principles" or "abstract reasons" of motion that Hobbes had developed in *De corpore*. Thus, the Hobbesian version of the principle of inertia receives the stamp of approval: no body begins to move itself if it is not moved by another adjacent body that is itself in motion; and, once moving, the body continues to move so long as nothing hinders it. Leibniz also expresses agreement with a principle that apparently contradicts the facts of sensory experience, one to which we will have to return when examining the paradoxes of the *Theoria motus abstracti*: a body at rest, no matter what size it is, can be displaced by the motion of another body, no matter how small this body is. Against the protestations of experience, Leibniz interprets, following Hobbes, the visible rest of a body as imperceptible motion. Already the principle of continuity is being appealed to in order to understand the correlation between the contrasting phenomenal appearances of motion and rest. However, more directly, Leibniz intends to develop a kinetic model to account for solidity. He thus questions Hobbes' interpretation, which reduced the cause of solidity to the body's reaction to impacts alone. Does visible solidity not endure in the absence of an impact presently affecting the body? And does it not endure despite the fact that, if one were dealing with a *sui generis* centrifugal motion, the presently unconstrained parts of the body should dissipate? Conversely, when constrained, the interference of an obstacle could only dissipate the reacting motive action of the parts in an instant. And there are other insufficiencies in Hobbes' position. According to this doctrine, the motive disposition from the center to the periphery that generates resistance to the impact would result from the concentration of a cause of motion in some given point; this remains to be explained. Moreover, the proportionality of the reaction to the action must render the solidity of bodies relative to eventual impacts; this does not seem to agree with experience, and the rational argument would instead force one to postulate that the more powerful the initial action is, the smaller the reaction must be.

In place of the paradoxical theory of Hobbes, which proves insufficient, Leibniz furnishes the elements of a physical theory of motion and its cohesive effects:

> I thought that, to produce the cohesion of bodies, the *conatus* of the parts orientated toward one another, that is, the motion by which they press upon one another, would have sufficed. For bodies exerting pressure on one another are in a *conatus* penetrating one another. The *conatus* is the starting point; the inter-penetration is the union. They therefore are at the beginning of a union. But when bodies begin to unite, their beginnings or limits become one with one another. Bodies whose limits reduce to a single one, or τὰ ἔσχατα ἕν [...], are not according to Aristotle's definition merely contiguous, but also continuous, and in truth one body whose movement is reducible to a single motion. If there is any truth to these reflections, you will appreciate that they cast the theory of motion in an original light. That bodies pressing upon one another are in a *conatus* penetrating one another remains to be proven. To exert pressure is to strive to invade a place still occupied by another body. *Conatus* is the first phase of motion, and therefore the first phase of existence in a place toward which the body is striving. To exist in the place where another body exists is to have penetrated it. Pressure therefore is the *conatus* of penetration. (A II 1^2 93–93; L 107)

Clearly, the notion of *conatus* introduced here refers to the motion that affects a part of a body in the initial state: it is an imperceptible incepting motion, whose effect is an imperceptible or so to speak virtual displacement of the material part subjected to the impact. In virtue of the Hobbesian principle of inertia, this motion must be produced via an effective displacement, and thus via an observable principle; but an instantaneous obstacle is produced by the *conatus* opposed to the part subjected to the impact, which creates an antagonistic effect. The *conatus* is endowed with a causal capacity for "penetrating" the extension of the part opposing it. To admit this possibility, one must suppose that there is no specific resistance to penetration that is extrinsic to the *conatus*, that is, to the incepting motion. Hence, the phenomenon of cohesion is represented in a purely kinetic way: the effect of extensive continuity is the result of *conatus* being united via their extensive elements, the physical points that generate the solid continuum. It obviously follows from this "phenomenist" framework that the productive cause itself, lurking in the background of the *conatus* as incepting motion, escapes sensory apprehension, if not also imaginative representation. Leibniz therefore ultimately questions the postulate of Hobbes, *Omnis motor est corpus*,[19] which does not seem justified to him in this context, and in light of the kinetic and purely phenomenal theorization of experience. If he praises Hobbes for having interpreted *sensio* as a permanent reaction, then the permanence of such an activity could never be founded as such in the physical world. This would involve developing a theory of mind (*mens*) that accounts for what is substantial in the background of corresponding physical activity.

19 Cf. in particular Hobbes, *De corpore*, II, ix, § 9 and x, § 0, OL I 111–12, 116–17, EW I 126, 131.

At the same time, in 1670, Leibniz distances himself somewhat from the Hobbesian philosophy of knowledge, a shift that will have a major impact on his theory of science. The *Preface to Nizolius* (1670) (A VI 2 398–444) suggests a very empiricist conception of the truth of propositions, since the analysis of statements via the understanding can only determine their clarity, and thus the combination of more or less simple terms that comprise them. Truth is the business of sensory apprehension, or the meaning of terms referring to sensory perception: "An utterance whose meaning is perceived by a percipient with the right disposition in the right medium is true, because clarity is measured by understanding, and truth by sense." (A VI 2 408–409; L 121) In addition, Leibniz adheres to a nominalist conception of the explanatory principles. He interprets Occam's maxim, *Entia non esse multiplicanda præter necessitatem*, as a parameter of the economy of presuppositions when it comes to determining the causes of phenomena. The best hypothesis is the simplest one, which is demonstrated by the prevalence in astronomy of hypotheses that only invoke simple motions. For this reason, Leibniz maintains, nominalists would have refused to rely on universals and realized abstract forms for their explanations. This amounts therefore to a rejection of the Aristotelian metaphysics of nature, which Leibniz endorses. He discerns in this interpretation of nominalism the foundation of the philosophy of the Moderns. Nonetheless, he criticizes the "ultra-nominalism" of Hobbes. Unsatisfied with reducing the universals to simple terms, the latter assumes that the definition itself of these terms refers to purely arbitrary groupings of names.[20] Hobbes thus disputes that the truth of propositions can depend on an objective order of phenomena represented by abstract terms. In opposition to this position, Leibniz asserts that changes to algorithmic notation in no way influence mathematical truths, and that one can in fact express them otherwise, so long as there is no disparity in the meaning of the truths that have been transcribed. When one is moving from the world of logico-mathematical propositions to that of propositions referring to sensory phenomena, the problem of identifying the foundations of induction presents itself. How can moral certainty be ascribed to the truth of a conclusion whose scope is presumed to be universal, when the implications of the propositions are limited to an aggregation of a finite number of particular cases? Leibniz's solution consists in postulating principles or rules of inference. These correspond to universal ideas or definitions of terms that describe how empirical facts are organized in order to formulate hypothetically necessary propositions. These definitions relate to causality and the sensory references of theoretical concepts. Thus, Leibniz formulates three rules of inference:

> (1) If the cause is identical or similar in every way, then the effect is identical or similar in every way. (2) The existence of a thing that is not perceived cannot be presumed. Finally, (3) everything that is not assumed must, in practice, be regarded as invalid before it is proven. (A VI 2 431)

20 Ibid., I, vi, § 14, OL I, 73; EW I, 83–84.

At this stage of development in his philosophy, Leibniz had clearly thought that scientific propositions can never be perfectly certain. Indeed, this would require that one operate strictly within the definitions of the terms by abstracting from every conceptual element referring to the experience of phenomena. But the norm for accepting explanatory concepts is precisely sensory experience. This goes hand in hand however with recognizing the rules of inference that guarantee demonstrations via prolepses, that is, anticipatory explanatory reasons. Even if in principle they ought to have been derived *a priori* by logically articulating propositions in simple terms, the justification for these prolepses depends *a posteriori* on the success of the explanatory schema. For these to translate the apprehension of phenomena via *sensio* in an adequate way, one must in effect rely on what Leibniz designates as auxiliary propositions founded on universal reason, which themselves could never be constructed inductively. With thinking and activity, or causality, having initially proven to be qualities or powers of the mind, everything suggests that in 1670 Leibniz is ready to connect the proleptic rules of induction to the reflexive experience of the *mens*, even if elsewhere he remains faithful to his empiricist conception of the truth.

The letters to Jacob Thomasius on 26 September/6 October 1668, and 20/30 April 1669, indirectly confirm the elements that will be relied upon to establish the new physics, which will take a nominalist approach to principles, like the one we just described. The aim of these letters is to reconstruct the notions of Aristotelian physics in such a way as to make them compatible with explaining bodies in terms of size, shape and motion, and in conformity with the approach of the Moderns. Herein lies the goal of the *philosophia reformata*: reconciling Aristotle with the mechanist natural philosophy of the Moderns. An important doctrinal movement in the 17th century, the *philosophia reformata*, included such major figures as Kenelm Digby, Thomas White, Jean-Baptiste Du Hamel and Jan De Raey in particular, whose *Clavis philosophiæ naturalis seu introductio ad naturæ contemplationem aristotelico-cartesianam* (1664) was particularly influential, as well as Erhard Weigel, whose teachings Leibniz had followed at the University of Jena.[21] Leibniz counts himself among the proponents of this reformed philosophy, but at the forefront so to speak, insofar as he truly imagines reinterpreting Aristotle's physics by applying the mechanical categories of the Moderns. In the *Preface to Nizolius*, he summarizes this reform program as follows:

> It seems that I have sufficiently reconciled Aristotelian philosophy with the reformed one. It is true that I must briefly consider the evident truth of the reformed philosophy. The following must be proven: that nothing exists in the world, but mind, space, matter and motion. [...] Now, it must be shown that nothing else is needed to explain the phenomena of the world and account for their possible causes, and above all, that there cannot be anything else. Besides, if we show that we need nothing else but mind, space, matter and

21 Cf. Mercer (1990); Bodéüs (1991).