JÜRGEN MITTELSTRASS

Leibniz's World: Calculation and Integration

INTRODUCTORY REMARKS

When a world looks back to view itself in the mirror of its becoming, it prefers to direct its gaze towards its founders. After all, it is not nature, but the product of human thought and action. If the modern world, which in this sense is above all the product of scientific and technological understanding, looks back, its gaze meets, alongside other great thinkers, Leibniz – the mathematician, natural scientist, engineer, logician, philosopher, jurist, science organizer, perhaps the last universalist, who still succeeded in uniting in his mind the essentials of the knowledge of his time and of a time yet to come. Leibniz who still thought the world as a unity, holding it together in his thought in all its aspects: scientific, technical, philosophical, ethical, and organizational. This will be my topic – under three points of view: the unity of science, the unity of the world, the unity of theory and practice.

1. UNITY OF SCIENCE

What was once a matter of course in science, but today seems to be something utopian, is the idea of the unity of science, understood as the unity of scientific rationality and scientific knowledge. If the world that we are seeking to understand with our knowledge is one world, why cannot scientific knowledge, too, be one, especially if it has reached its aim, that is, the comprehension of the world? Leibniz's name is linked to the perhaps most impressive attempt not only to think this unity, but to provide it with the necessary instruments. The keywords are: the *Leibniz programme* and the *mathesis universalis.*

We understand the Leibniz programme as Leibniz's endeavour to develop a scientific language that succeeds in representing the order of the world in a scientific manner. The core of this programme is accordingly the construction of a (scientific) artificial language, which, on the basis of a theory of signs (*ars characteristica*) for the representation of states of affairs and their relations to one another by means of procedures of mathematics and formal logic, was to provide material inference with the formal certainty of calculation. It is the aim of such an artificial language to equip scientific analysis – and philosophical analysis as well – with an exact organon. The simple instruction then reads: "*calculemus*".[1]

Leibniz's intent here is not only to construct a formalism for representing knowledge, but also to construct a formalism for discovering knowledge. The connection is formed here by the complementary methods of analysis and synthesis familiar from mathematics, whereby Leibniz seeks to assign the *ars*

[1] Draft for the "Initia et Specimina Scientiae generalis," in *Die philosophischen Schriften von G. W. Leibniz*, vols. I–VII, ed. C. I. Gerhardt, Berlin 1875–1890, vol. VII, p. 65. For a detailed presentation of the Leibniz programme see J. Mittelstrass, *Neuzeit und Aufklärung. Studien zur Entstehung der neuzeitlichen Wissenschaft und Philosophie*, Berlin and New York 1970, pp. 435–452.

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inveniendi for which he was searching to the analytical method and the *ars iudicandi* to the synthetic method, while at the same time stressing the inventive character of both methods: "There are two methods: the synthetic, or that by means of the combinatorial art, and the analytic. Each of them can point out the origin of invention – for this is not the privilege of the analytic. The distinction lies in the fact that combinatorics is a complete science or at least displays a series of theorems and problems, including that which is sought. Analysis on the other hand reduces a proposed problem to a more simple one."[2]

Furthermore, in this context Leibniz points to algebra and to the idea of calculus: The intention is that "truths of reason, just as in arithmetic and algebra, can also be reached in every other field in which inferences are drawn as it were by a calculus."[3] The paradigm of such a calculisation in turn is the infinitesimal calculus developed by Leibniz and the various logical calculi which are applications of a *characteristica universalis.*

Mathesis universalis – this is then the attempt to represent in mechanistic or algorithmically controlled dependencies the structure of the formal sciences or the sciences that work with formal means. Although this is not successful in the intended sense of really producing the unity of science both in general and specifically, it does at least mean the beginning of modern logic and of modern philosophy of science. This holds true for a framework marked out by problems of the syntax and semantics of formal languages as well as for a philosophy of the natural sciences, which is essentially characterized today by the problem fields of theory structure, theory dynamics, and theory explication. While this is primarily determined by tasks of analysis of the *theory form* of scientific knowledge and only secondarily by concerns connected with the *research form* of (scientific) knowledge, Leibniz tries to accommodate both tasks in the same manner. In this he supports himself with a peculiar apriorism, which Kant will later share. He holds that the "truths of reason" in the order of knowledge sought for are at the same time the truths of the world, meaning a scientific world. This is, from a philosophical point of view, the inherent rationalism of the Leibniz programme and of the scientific architecture of a world that follows it, which could be called the *Leibniz World*. I shall come back to this world later on.

Leibniz proposed to entrust the elaboration of the idea of a unity of science in the form of a *mathesis universalis* to an academy; he obviously did not expect the universities to be able to carry out such a programme, which would demand a systematic and organizational restructuring of science. This academy – Leibniz also thought about this kind of practical matters – was to be financed by the proceeds from his inventions in the Harz mining enterprises.[4] The inventor as an organizer and entrepreneur – this unity, too, was in good hands with Leibniz. As a further organizational expression of the unity of science, Leibniz also envisioned a network of academies, which would unite themselves in a sort of world academy. Already around 1669 he had, in the tradition of utopian thinking, formulated the concept of an internationally structured, still monastically organized "*Societas philadelphica*",[5] which was to deal especially with medicine, but also with manufacture and commerce.

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[2] L. Couturat, *Opuscules et fragments inédits de Leibniz*, Paris 1903, p. 557.

[3] Part of an unsent letter to C. Rödeken from 1708, *Philosophische Schriften*, vol. VII, p. 32.

[4] Letter to Herzog Johann Friedrich from Autumn 1678, February (?) and March 29, 1679, *Sämtliche Schriften und Briefe*, ed. Prussian (today Berlin–Brandenburg) Academy of Sciences, Berlin 1923ff., vol. I/2, pp. 79–89, 120–126, 153–161.

[5] See *Sämtliche Schriften und Briefe*, vol. IV/1, pp. 552–557.

2. Unity of the world

What seems to underlie a unity of science, namely a unity of the world, is according to Leibniz in fact a construction, which falls not so much within the jurisdiction of the scientific understanding as it does in that of the philosophical. It is a peculiar world that we encounter in Leibniz's attempt to bring this unity to expression. It is the world of *monads.*

Leibniz understands monads as conceptual unities; the path to these passes once again by way of formal and physical considerations. The point of departure are some simple considerations of continuity and the formulation of a principle of continuity, as well as work on a differential calculus[6] that seems to force him to abandon the concept of the corporeal atom as conceived in physical atomism.[7] Systematically quite close to the modern concept of a point mass, Leibniz's theory assigns elementary physical units to points in geometric space and interprets these units as centers of force. This is justified by the fact that differential geometric points on space curves can be assigned acceleration vectors which correspond to physical forces, if the curves are conceived of as trajectories of moving masses. Accordingly, the expression *(material) atom* is replaced by the expressions *substantial atom*, *formal atom* or *metaphysical point*[8] and after 1696 by the expression *monad*. Within the framework of the so-called monad theory and in the transition to the conception of a logical atomism, the concept of a monad signifies the programme of designating elementary units (also in dynamics) by conceptual unities, that is the monads.[9]

In a philosophical context, this conception, with which older concepts of substance are also reconstructed, leads to some central propositions which characterize a *Leibniz World* internally. Among them are the propositions: (1) Every monad represents ("mirrors") the universe. (2) Between monads, especially body-monads and soul-monads there exists a pre-established harmony. Propositions like these sound strange and speculative, but they prove on closer scrutiny to be nevertheless logically reconstructable. Thus the second proposition asserts that every action or every event can be understood as the realization of a prior (not temporally but logically) existing aggregate complex in a physical context, for instance, an infinite physical aggregate system. The logician looks over the shoulder of the metaphysician, and so does the scientist.

In a small German-language work from 1695 Leibniz writes, alluding to the representation theorem of monad theory (the first proposition cited above) and the *perspectivism* of perception and of knowledge linked with it: "We have to put ourselves with the eyes of our understanding where we do not and cannot stand with the eyes of our body. For example, if we consider the course of the stars viewed from the globe on which we stand, then a wonderfully confusing thing arises, which astronomers in thousands of years could scarcely reduce to certain rules (…). But once it was finally discovered that one must put his eye in the sun, if he wants to consider the course of the heavens rightly and that thereupon everything turns out beautifully, then one sees that the purported disorder and confusion was the fault of our understanding and not of nature."[10] Leibniz appeals, as does Kant later on, to Copernican astronomy (without explicitly

[6] "*Nova methodus pro maximis et minimis* [...]," *Acta Eruditorum* 3 (1684), pp. 467–473.

[7] See "*Specimen dynamicum*" (1695), *Mathematische Schriften*, vols. I–VII, ed. C. I. Gerhardt, Berlin and Halle 1849–1863, vol. VI, p. 248.

[8] "Système nouveau" (1695), *Philosophische Schriften*, vol. IV, p. 482.

[9] *Op. cit.*, p. 483.

[10] "Von den Verhängnissen," *Philosophische Schriften*, vol. VII, p. 120.

mentioning Copernicus) to explicate an epistemological reorientation linked to the monad theory, which consists in locating the conditions of knowledge neither in the phenomena nor in perception, but in the work of the (constructing) understanding. In the language of monad theory: we are dealing in the work of the scientific understanding with phenomena as *phenomena bene fundata*,[11] that is phenomena grounded in conceptual or theoretical constructions. The world of appearances, "the general system of phenomena", as Leibniz calls it,[12] is not given "in itself" but is the product of intuitive and conceptual (theoretical) constructions. These constitute, in science as well, special worlds, *Leibniz Worlds.*

This has had the result that the concept of the monad has had a career in other scientific settings, for instance in non-standard-analysis, where it is proposed that every real number is surrounded by a monad made up of infinitely many "hyperreal" numbers, as well as in the theory of functional programming.[13] Monads can also be conceived of as calculating machines – this is completely in line with Leibniz, who occupied himself with the construction of calculating machines and who founded dyadics and determinant theory,[14] which are of great importance to computer technology. What is striking is how Leibniz is able to conceive of opposites, which philosophers love so much and which seem fundamental to the structure of our world – here calculating machines and life – as a unity, both speculative and logical at the same time. What stands in opposition is for him not substance, but the appearance, even though the philosophical tradition and frequently also the scientific tradition like to see it the other way round. Even more: Leibniz overcame the opposition between being and appearance long before Hegel and even more clearly than Hegel. Not because being becomes semblance and semblance becomes being, but because both are conceived as phenomenal forms of something underlying. According to Leibniz this underlying thing is again nothing concrete, but something conceptual, the concrete symbolic representation of the conceptual, the monad.

In this way Leibniz manages to grasp as one the artificial and the natural, the concrete and the abstract, the empirical and the conceptual, the machine-like and the life-like, what calculates and what breathes. It is the mind that thinks the whole (the world does not think itself). And not only the unity of science and the (thought) unity of the world belong to this whole, but also the unity of thinking and acting, theory and practice.

3. Unity of theory and practice

Leibniz's well known formula which is supposed to express the unity of theory and practice, the unity of science and life, reads "*theoria cum praxi*"[15]. It asserts: "If we regard the disciplines in and for themselves they are all theoretical; if we regard them under the point of view of their application, they are all

[11] Letter to B. de Volder from 1705, *Philosophische Schriften*, vol. II, p. 276.

[12] *Discours de métaphysique* § 14, *Philosophische Schriften*, vol. IV, p. 439.

[13] See P. Rechenberg and G. Pomberger (eds.), *Informatiklehrbuch*, Munich and Vienna 1997, pp. 450–452.

[14] See H. J. Greve, "Entdeckung der binären Welt," in *Herrn von Leibniz' Rechnung mit Null und Eins*, Berlin and Munich [3]1979, pp. 21–31; E. Knobloch, "Erste europäische Determinantentheorie," in E. Stein and A. Heinekamp (eds.), *Gottfried Wilhelm Leibniz. Das Wirken des großen Philosophen und Universalgelehrten als Mathematiker, Physiker, Techniker*, Hannover 1990, pp. 32–41.

[15] See *Deutsche Schriften*, vols. I–II, ed. G . E. Guhrauer, Berlin 1838/1840, vol. II, p. 268.

practical."[16] And it asserts further that the disciplines, the sciences have to be made practical, that means application oriented. Theory and practice are not strangers to each other, science and life are not different worlds.

On May 12, 1700 Leibniz writes in connection with his academy plans: "In time I would like to have something from which to expect real utilities and not merely curiosities."[17] That means that according to Leibniz, science has to prove its potential not only with regard to a theoretical interest, but also to a practical interest. The point is to solve not only the problems that science itself poses, but also the problems that the world poses; in this context Leibniz explicitly mentions problems of foodstuff supply and of disease. Thus his interest in the solution of *technical* problems and in the construction of machines. Whether one considers his construction of a calculating machine or his construction of pumps and cylinders, especially his construction of a rotary vane pump[18] for the Harz mines, or of the (mathematical) solution of mechanical problems like the calculation of the elastic resistance of a loaded beam, which has technical relevance,[19] the point of view in the foreground is always that knowledge has to become practical, that the problem is not only to describe the world (by theoretical means), but also to change it (by technical means) to the better.

The "best of all possible worlds", which Leibniz sees as already actualized among other things with reference to the applicability of extremal principles in physics – that is propositions, that describe physical systems in which one parameter takes on an extreme value, usually a minimum as in the case of the so-called Principle of the Least Action –, should also be realized in practice, that is, in the affairs of the world. This is a long argument. In Leibniz' philosophical reflections, the reason of the world is grounded not only in the (hidden) reason of the facts, among these physical facts, but also in the reason of God. In a kind of theology of knowledge, discourse about the physical nature of the world and the epistemic nature of man combines with discourse on God.[20] "We see all things through God," we read in the *Metaphysical Discourse* of 1686: "So it can be said that God alone is our immediate object outside us and that we see all things through him."[21] Science becomes a theologically grounded undertaking here. The order of knowledge is preceded by an order of the world, a divine order. "Objective" rationality according to Leibniz has its ground in a divine "subjectivity", in the divine intellect.[22] The unity of the world, which Leibniz in his *mathesis universalis* seeks to describe as a unity of knowledge and science, in his metaphysics as the representation of the universe in each substance, in each monad, is described in these pious metaphors as a unity of the world with

[16] *Dissertatio de arte combinatoria* (1666), *Sämtliche Schriften und Briefe*, vol. VI/1, p. 229.

[17] *Deutsche Schriften*, vol. II, p. 145.

[18] See H. P. Münzenmayer, "Leibniz, der Erfinder der Drehschieberpumpe?," *Studia Leibnitiana* 10 (1978), pp. 247–253; also J. Gottschalk, "Technische Verbesserungsvorschläge im Oberharzer Bergbau," in E. Stein and A. Heinekamp (eds.), *Gottfried Wilhelm Leibniz* (see footnote 14), pp. 62–71.

[19] See H. Wussing, *"Ars inveniendi* – Leibniz zwischen Entdeckung, Erfindung und technischer Umsetzung," in K. Nowak and H. Poser (eds.), *Wissenschaft und Weltgestaltung (Internationales Symposion zum 350. Geburtstag von Gottfried Wilhelm Leibniz vom 9. bis 11. April 1996 in Leipzig*), Hildesheim and Zurich and New York 1999, pp. 231–253.

[20] On the following see my "Philosophie in einer Leibniz-Welt," in I. Marchlewitz and A. Heinekamp (eds.), *Leibniz' Auseinandersetzung mit Vorgängern und Zeitgenossen*, Stuttgart 1990 (*Studia Leibnitiana Supplementa* XXVII), pp. 9ff.

[21] *Discours de métaphysique* § 28, *Sämtliche Schriften und Briefe*, vol. VI/4B, p. 1573.

[22] See A. Gurwitsch, *Leibniz. Philosophie des Panlogismus*, Berlin and New York 1974, pp. 23ff.

God and with the knowing subjects. At the same time Leibniz draws from this description the conclusion that *morality*, too, must be connected with metaphysics[23] – not only the knowing subjects, but also the moral subjects are included in this pre-established harmony between God and the world and in this inwardly drawn unity of theory and practice.

It is above all the contemplative character of this harmonious synthesis, that makes such a notion of knowledge and of the position of man in the world appear so strange. Theological, cosmological and anthropological metaphors, that combine themselves into the metaphor of the unity of the world in God describe a different world. Not the world in which we live and probably not even the world in which Leibniz lived. On the other hand the point in philosophy is not to describe the world as it is. This descriptive task is served by the empirical sciences – at least this was the understanding of science in the early modern period. What matters to the philosopher Leibniz is to expose the inner order of this world, which is not only an order of physical things and processes, and to describe the reason of the world in it.

However this is accomplished already with Leibniz in such a way that what is *described* is something that has first to be *produced* in order for it to be described. This happens in the work of the scientist as well as in the work of the philosopher. That means that the reason of the world, which Leibniz presupposes in scientific and philosophical respects, is strictly speaking nothing that we can just take for granted, but it remains something that we *ought to want*. After all what matters to Leibniz himself is not merely the description of a rational world, which at the same time might be our world, but the production of a world that could become our world. This is the conception of Leibniz that has to be carried over into our time. After all "*theoria cum praxi*" is not only a scientific and technical principle, but also an *ethical* principle. Or formulated differently, but still in Leibniz' terminology: the measure of the world is also an ethical measure.

Concluding remarks

Today we admire Leibniz as the universal scientist who in his scientific production was like a university unto himself, the great philosopher who brought philosophical profundity to knowledge and a scientific expression to philosophy, the ingenious constructor, who brought theory into construction and the constructive elements into theory, and the person who held all this together in his thought. But while we admire Leibniz, we also historicize him and forget that we can also learn from him. Two remarks to this point.

We are living today in an *experts' world*. This world lives from an increasing particularization of knowledge, just as the world of science has evolved into a world of specialists. In a certain sense this is an inevitable development, but in this development something essential is lost, that is, the ability to think in larger relations and to orient ourselves in larger contexts. In a world of experts, knowledge loses its orienting function. That is why orientation knowledge today is also in a bad state. The world has at its disposal enormous amounts of knowledge and enormous amounts of information, here in form of transported knowledge, but nevertheless it is constantly getting weaker in its orientation. It is surfeit that makes us losers, and the inability to link the knowledge of the

[23] *Discours de métaphysique* § 35, *Sämtliche Schriften und Briefe*, vol. VI/4B, p. 1584.

specialist and the skill of the expert with other knowledges and skills. Precisely this is the idea that comes to the fore in various notions of unity in Leibniz – the unity of knowledge and science, the unity of the world and the unity of theory and practice. It does so, metaphorically speaking, in a monad in which a universe is mirrored. Therefore a *Leibniz World* is also an orientational world – and Leibniz himself is the epitome of this world.

But we live not only in a world of experts and specialists, in our science we also live in a world in which the particularization of knowledge corresponds to the particularization of the *institutional* forms of knowledge, where an epistemic particularization corresponds to an institutional. In this world, the scientific institutions do not follow the actual development of research and science, but rather the development of research and science follows a given institutional order. We are constantly speaking of inter- and transdisciplinarity, which is supposed to inherit the scientific future, but we nevertheless cling to a system of science divided into subsystems inside and outside the university as if this were a god-given order. The idea that Leibniz pursued was completely different. His academy plans, directed against the paralyzed reality at the universities, were to bring together research and at the same time give it a basis between science and life from which it could operate freely. An open institutional form of knowledge was to replace the closed institutional form of knowledge. That is why the philosopher Adolf Trendelenburg, secretary of the academy more than 150 years after Leibniz founded it in Berlin, admonished this academy to be an "imperishable Leibniz".[24]

According to Adolf Harnack, who wrote the history of Leibniz' academy in 1900, Leibniz was the soul of the academy,[25] which was for its part the center of the scientific world. It would be good, if our scientific world, in which the specialist rules and no system, no unity of science, be it systematic or organisational, is discernible, could rediscover this soul.

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[24] A. Trendelenburg, *Leibniz und die philosophische Thätigkeit der Akademie im vorigen Jahrhundert. Ein Vortrag, gehalten am Gedächtnistage Leibnizens, am 1. Juli 1852, in der Königlichen Akademie der Wissenschaften*, Berlin 1852, p. 1.

[25] A. Harnack, *Geschichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin*, vols. I–III, Berlin 1900, vol. I/1, p. 183.