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Hans Jonas, The Thinker of Ontological and Scientific Revolutions

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1. Introduction.

As most twentieth-century thinkers with a background in the German philosophical tradition, Hans Jonas is concerned with the understanding of modernity as radically new, original, and different from its cultural, philosophical, and historical other, antiquity. The starting point for this philosophical enterprise is the opposition set by the imaginary *querelle des anciens et des modernes*, which emphasizes the break with the past as a principle of thinking (OSR 132).[1] Among the many faces of modernity Jonas is particularly interested in science as one of its defining moments.

The very first course Jonas taught when he joined the Graduate Faculty of Political and Social Science at the New School for Social Research in 1956 was the course on ontological and scientific revolutions, which he later repeated several times. The text of the 1967 lectures shows the full extent of Jonas' engagement with the question of what constitutes modernity ontologically, in its understanding of being in its various aspects: being as thought, being of the world, being in the world, and being as questioning the meaning of the world and of being itself. The lectures are particularly instructive, since they show Jonas' renewed interest in "the marvel of modern science" (OSR 26) in its history and contemporary practice, as well as many of the same concerns that he explores in his work at that time and later. The reflection on modern science as grounded in a novel ontology with new possibilities and limitations constitutes the core of Jonas' philosophical engagement with the understanding of human life as grounded in nature (in *The Phenomenon of Life)*, and at the same time becomes the foundation for the moral normative stance toward securing the life of future generations (in *The Imperative of Responsibility*).[2]

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[1] Hans Jonas. Ontologische und wissenschaftliche Revolution/ Ontological and Scientific Revolution. Kritische Gesamtausgabe der Werke von Hans Jonas (KGA). Bd. II/2. Ed. Jens Peter Brune. Freiburg-Berlin-Wien: Rombach Verlag, 2012, p. 3-197. Henceforth referred to as: OSR, followed by the page number. Over the course of fourteen lectures, Jonas keeps questioning, patiently, carefully and rhetorically impeccably, the foundations of modern science in Copernicus, Kepler, Bruno, Nicolas of Cusa, Galileo, Bacon, Descartes, and Newton, with references to Whitehead, Santayana, Michael Polanyi and Koyré. While lecturing, he also often proceeds by dialectical engagement with the students through questions and answers, even if occasionally the question is not passed on to us ("A question is raised which is inaudible due to the passing airplane," as a remark imperturbably suggests, OSR 156).

[2] Hans Jonas. The Phenomenon of Life: Toward a Philosophical Biology. Harper & Row, New York, 1966; Hans Jonas. The Imperative of Responsibility. In Search of an Ethics for the Technological Age. Trans. by H. Jonas with the Collaboration by D. Herr. Chicago-London: University of Chicago Press, 1984. (Originally publ. as: Das Prinzip Verantwortung. Versuch einer Ethik für die Technologische Zivilisation. Frankfurt am Main: Insel Verlag, 1979.)

2. Revolution and modernity.

Modernity for Jonas is marked by a radical novelty, which transpires both in the new understanding of the world and in our self-understanding as being humans who determine how and what the world is in thought. The modern human capacity for thought is intentionally self-conscious, ruthlessly critical, and ceaselessly radical in the ultimate quest for the full transparency of both thinking itself and the world. This novelty amounts to revolution, which is a multifaceted phenomenon. In this context, Jonas is primarily interested in the vision and account of the new science. One might say that the "scientific revolution" of the 16–17th centuries is anachronistically named after the French Revolution of the end of the 18th. And yet, it is probably the other way around: the political and social revolution is made possible as a realization of the new understanding of the world and especially of the human being. The opening statement of Jonas' lectures runs: "'*Revolution*' suggests a *sudden* event. What is commonly understood when revolution is applied to change? It has a certain *violence*, a *radical* nature, a *comprehensive* scope. It is a word applied to major, not minor changes" (OSR 3).[3] Put otherwise, revolution is an event that is (1) unexpected and unpredictable, which, however, appears certain and necessary *after* the event in its philosophical explanation and cultural procession, as presumably prefigured by the whole previous development. Revolution is (2) violent, insofar as it intends to establish a radical break, a rupture with the past, and to liberate itself from the deadening schemes of thought and action. As Jonas puts it: "We speak of revolution when the change in question – a collective change in human affairs – is radical in nature, comprehensive in scope, and concentrated in time."[4] This means that revolution also (3) occurs in a relatively short time span and (4) involves everyone, in one way or another, into in the revolutionary activity. However, one should notice, first, that the time of scientific or artistic revolution is spread usually through two or three generations, from founders to their disciples. Second, revolution is collective action that brings about changes and transformations to the lives of many people, yet the active revolutionaries are themselves relatively few. Moreover, since the revolutionaries tend to critically distance themselves from existing institutions, quite often they are not professionals but rather vocational amateurs: Bacon, Descartes, Spinoza, Leibniz never held official university professorial positions.

Furthermore, revolution is always (5) *radical*, which means that it always goes to the root, to the beginning, principle, *arkhē*, uprooting the old and planting the new (OSR 129, 133–134). And yet, similarly to the revolution of the sky, the new might be thought as the restoration of an original,

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[3] At the time when Jonas was delivering his lectures, Kuhn's thesis about scientific revolution as the rapid change of paradigms became much discussed. See: Thomas S. Kuhn. The Structure of Scientific Revolutions. Chicago: Chicago University Press, 1996 (3rd ed.; originally publ. in 1962).

[4] Hans Jonas. "Seventeenth Century and After: The Meaning of the Scientific and Technological Revolution." Philosophical Essays: From Ancient Creed to Technological Man. Englewood Cliffs, 1974, p. 45-80, p. 45 (originally publ. in: Philosophy Today 15 (1971), p. 76-101). Cit. ap.: Jens Peter Brune. Einleitender Kommentar. In: KGA II/2, p. IX-XL; p. XVII.

simple, and true meaning of things that was later distorted or lost.[5] Revolution allows for a new vision—a *re*-vision—of the world and our place and action in it—political, social, artistic, and scientific. Revolution thus presupposes the understanding of our previous activity as outdated and pre-revolutionary, and hence in need of a radical rethinking and change. In particular, the scientific revolution comes with (6) a new foundation of thought based on the new self-confidence and the distrust of authority, marked by the systematic doubt elevated by Descartes into the epistemological starting point that makes possible an entirely new knowledge (OSR 3—5).[6]

In short, revolution is marked by novelty and radicalism, and scientific revolution—by the new understanding of the world, which makes the world, at least for a while, an unusual place to observe and live in. For Jonas, among the main features of the scientific revolution that make this new picture recognizably different from the "premodern" one are: the new account of the cosmos in its (heliocentric) structure, the rethinking of the concept of the cause (by deposing the final causality), the introduction of the infinite into the world, the stressing of rational necessity along with empirical contingency, the disposal of the "occult qualities," the rethinking of the notion of substance, the new understanding of motion and change by means of mathematics, and the introduction of the notion of quantifiable and mathematically expressible laws of nature (OSR 281). Similarly to most modern philosophers of science, Jonas takes the new science to be represented first and foremost by physics, particularly by celestial mechanics transposed and converted also to the study of the terrestrial motion that, for the first time in history, is grasped in its elusive change by the rigorous means of thinking primarily represented by mathematics. "*What does the interpretation of nature mean?*" —asks Jonas—"It means the explanation of changes, and these are in the last resort always motions and changes in conditions of motion that are observed by the laws of the new science of Newtonian physics" (OSR 188). The task of such an interpretation, then, is to account for the changes *mathematically*, rather than to explain their origin and end. For this reason, in what follows, I will mostly concentrate on the discussion of the new ontology and the role of mathematics in new science.

3. Three components of the scientific revolution.

The new picture of the world that emerges as a result of the scientific revolution, according to Jonas, has new *aesthetic*, *logical*, and *mathematical* traits that explain its advantages over the old account (OSR 49). I will first discuss the aesthetic and the logical traits, although my primary interest is the mathematical aspect, to which the other two converge.

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[5] See: Hannah Arendt. On Revolution. New York: Penguin, 1990 (orig. publ. 1965), p. 42; Artemy Magun. Negative Revolution. New York-London: Bloomsbury, 2013, p. 6-8; Reinhart Koselleck et al. "Revolution." In: Geschichtliche Grundbegriffe. Ed. by Otto Bruner, Werner Conze, Reinhart Koselleck. Stuttgart: Klett, vol. 5, p. 653-788.

[6] In Jonas' words, "The Cartesian philosophy is the most radical expression of the new philosophy. In a sense it is a founding event, or feat, of modern philosophy as a whole." (OSR 165; cf. 131). However, this Cartesian radicalism for Jonas is a only a post factum assertion and ontologization of what the modern mind has comes to believe and convinced itself: "Descartes offers his revolutionary upheaval as a kind of game, a post factum (for him) vindication of what he had convinced himself of before." Jonas (OSR 139).

4. New aesthetics: Harmony.

The aesthetic aspect of the scientific revolution transpires in two of its features: in the *harmony* of celestial motions in Kepler (OSR 33), and in the *simplicity* of the constituents of both the world and knowledge. Harmony attests to the either apparent or concealed beauty and first becomes visible in Renaissance painting, which is a sui generis "revolution" of returning to the ancient ways of depicting beautiful bodies and their interactions. Jonas, with his life-long interest and admiration for Renaissance painting (particularly, for Giovanni Bellini), argues that the new painting both studies and stresses proportion and geometrically constructed perspective, and depicts motion, rather than static posture. One might also add that Renaissance painting presents and represents the phenomena according to their appearances and implicit *mathematical* laws and proportions, rather than in their inner static eternal essence. For this reason, the painters portray not only the surface of the body but also study its inside structure as the "instruments of motility," as Jonas calls them—"the muscles and bones and joints"—that transpire through the dynamic depiction of the surface (OSR 16–17).

Harmony, then, appears as an aesthetic criterion for the evaluation of the newly discovered and depicted world. In particular, the principle of harmony becomes for Kepler not only an evaluative or descriptive principle, but an *explanatory* heuristic one. Such a harmony is primarily present in proportions, which are both seen and thought in painting, as well as in the motion of the planets, and are describable mathematically: "these mathematical proportions . . . were at the same time *also* the *rational explanation* of *why* the planets moved this way . . . the *ideal* mathematical *form* of movements is the *reason* for the movements to be that way" (OSR 34).

5. Simplicity.

The other aesthetic constituent of new science is simplicity, which is both the simplicity of the world in its constituents and of the knowledge of this new world. Understanding nature as uniform and simple becomes fundamental for Galileo (OSR 68–71, 77), as well as for Newton, who says in Rule I of the Rules of Reasoning in Philosophy in the *Mathematical Principles of Natural Philosophy*: "Nature does nothing in vain, … for Nature is pleased with simplicity" (OSR 173).[7] In describing such a nature, the thinkers of the newly seen and (re)discovered universe also make an "effort to achieve utter simplicity" (OSR 181). But what is this simplicity? It is the simplicity of both being and of the vision of this being. That the mottled multiplicity and the apparent variety of phenomena might have just a few underlying basic structures was commonly thought already in ancient physics in the Presocratics, Plato, Aristotle and the Stoics. Yet, none of the ancient thinkers considered it possible to study and describe the flux and transformation of natural things

[7] Isaac Newton. Mathematical Principles of Natural Philosophy and His System of the World. Translated into English by Andrew Motte in 1729. The translation revised, and supplied with historical and explanatory appendix by Florian Cajori. 2 vols. Berkley: University of California Press, 1966. Vol. 2, p. 392. See also: Philosophiae naturalis principia mathematica. The third edition (1726) with variant readings. Assembled and ed. by A. Koyré and I.B. Cohen. 2 vols. Cambridge (Mass.): Harvard University Press, 1972.

in the precise terms of mathematics. Plato describes the fundamental constituents of material things as geometrical triangles, yet never told us how they are translated into physical properties (e.g., weight) or how they can be applied to the study of locomotion (*Tim.* 53b–63e). And Aristotle provided a theory of change of natural things, which, however, was not mathematical but a qualitative study of the principles, elements, and causes of natural phenomena (*Phys.* 184a10 sqq.; *De gen et corr.* 314a1 sqq.). For all antiquity, the study of being in ontology and mathematics is decisively different in its object and methods from the study of becoming in physics.

But for modern science the being of the world *is* in becoming, which is why "the analysis of nature is ultimately the analysis of motions" (OSR 71). Moreover, the very terms in which motions can be conceived are *quantifiable* magnitudes and forces (OSR 73) that can be known and described by strict means, which are primarily mathematical. The new simple components of nature are physical atoms or particles, represented as and studied by mathematical indivisibles, which are rethought as infinitesimals by Newton and Leibniz.[8] In cognition, these simple constituents are captured by simple ideas that allow for the reduction of the manifold complexity of phenomena to the simplicity of a few principles, elementary magnitudes, and basic forces (which in Newton account for two aspects of matter, inertia and gravity [OSR 186; cf. 171, 175, 178, 182]) that should be then accessible to analysis in thought. As Jonas stresses, this simplicity of nature is a kind of axiom in the natural philosophy of Galileo.[9] I would think, however, that it is much more a postulate, which means that rather than being self-evident, it becomes a task to be achieved and accomplished by the efforts of modern scientists and philosophers.

6. Ideas and method.

The new simplicity of the known is also reflected in the simplicity of the knower and the known, represented in ideas. Unlike the Platonic idea, which is the real unchanging thing of which physical things are fluent and imprecise reproductions, the modern idea is a mental representation of a thing out there, and as such is "something that is in *me*" (OSR 141). But since we can understand the world only in terms of and on the basis of ideas, then some of them, which Descartes famously labels "clear and distinct" (*Disc.* II, AT VI 18 et passim), cannot be mistaken.[10] Clear and

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[8] Newton investigates this already in his student Trinity Notebook, where he discusses the question "Of the First Matter. " See: J. E. McGuire, M. Tamny. Certain Philosophical Questions: Newton's Trinity Notebook. Cambridge: Cambridge University Press, 1983, p. 336-337.

[9] Galileo Galilei. Discoveries and Opinions of Galileo. Trans. with an Introduction and Notes by S. Drake. New York: The Modern Library, 2001 (first publ. 1953) and Galileo Galilei. Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican. Trans. by S. Drake, Foreword by A. Einstein. New York: The Modern Library, 2001 (first publ. Berkeley-Los Angeles, 1967).

[10] As Jonas puts it, "There must be trust in something. The central principle in Descartes is: I must trust my own insight on the rigorous criterion that I let pass only what is clearly and distinctly perceived by me. …It is not a sweeping assertion about the nature of our mind, but it is a minimal assertion—that at least something deserves trust." (OSR 148). And: "The basic rule is: only to accept what is clearly and distinctly presented to me, and behind this rule there stands the more or less metaphysical conviction that what is clearly and distinctly perceived is not only true, but that what is presented in this clear and distinct manner… are ultimate elements of reality itself. The ultimacy of the

distinct ideas that are perceived in such a way that one cannot be mistaken about them, their object and the very act of perception, become then a "certificate of truth" (OSR 155). In the fully transparent and self-reflective act of perceiving, which at the same time is the act of knowing, the completely intelligible comes to coincide with the completely real (OSR 153), and thus with the undeniably true. In other words, in Jonas' aphoristic formulation, "The *epistemological* simplicity is at the same time the *ontologically* elementary" (OSR 152). The ontological structure of the world, then, not only maps but also coincides with its epistemological reflection, both of which should be based on simple constituents. Therefore, clear and distinct ideas are themselves the elements of reality, and thus our knowledge of reality should be of the same kind and form as this reality is: clear, distinct, simple, and precise.

To think the simple is simple yet, at the same time, very difficult. For, on the one hand, one needs to think simple things: one needs ideas. But on the other hand, one needs to combine these things into formulations and propositions: one needs method. Since such a method is a further reflection of the postulated simplicity of the world and simple ideas, it should be, on the one hand, rational, unambiguous and thus unique. And, on the other hand, it should be simple and *easy to use*, almost effortlessly leading to the understanding of the world and its properties (in Bacon's *Novum Organum*,[11] Descartes[12] and Leibniz [OSR 91, 129]). However, since the world (or at least the scientific ideal of the world) is complex in its phenomena yet simple in its principles and constituents, the complexity should be reduced (by *metodo resolutivo* in Galileo [OSR 70] and by analysis in Descartes [OSR 170—171]) to simple constituents, from which true propositions should be then deduced (by *metodo compositivo* in Galileo and synthesis in Descartes). In Jonas' words, this is "a reduction of the complex and the obscure to the simple and therefore clear and distinct, and the recombination of these simple elements in a deductive process of reasoning which reconstructs the world from these simple natures" (OSR 153). The two operations of the mind that make the method work are intuition and deduction (Descartes, *Reg.* IV, AT VI 372; XI, AT VI 407–408). Intuition allows for understanding and grasping the "*utterly simple ideas*" (OSR 143), which themselves are *not* propositions; and deduction allows to connect and combine or—to use Plato's metaphor (*Polit.* 305e–306a)—weave them together by means of the method's rules into chains of reasoning arranges by "*ordo et mesura*" (Descartes, *Reg.* IV, AT X 378, 451) that lead, through divisions, arrangements, and enumerations, to true propositions and knowledge, including that of the world. Complex phenomena thus should be analyzable into simple notions, and then complex theories should be constructible out these simples, which are a *sui generis* mathematical

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reduction to the simple in terms of clearness and distinctness is at the same time the ultimacy of the reduction of nature to its own ontic elements." (OSR 152).

[11] Francis Bacon. The New Organon. Ed. By L. Jardine, M. Silverthorne. Cambridge: Cambridge University Press, 2000, Bk. II.

[12] "By a 'method' I mean reliable rules which are easy to apply, and such that if one follows them exactly, one never will take what is false to be true or fruitlessly expend one's mental efforts, but will gradually and constantly increase one's knowledge till one arrives at a true understanding of everything within one's capacity." R. Descartes. Reg. IV, AT X 372; cf. Disc. I, AT VI 3.

atoms. The two constituents of the method are therefore the analysis, for which the paradigm is the "algebra of the modern" (Descartes, *Reg.* IV, AT X 373-377; *Disc.* II, AT VI 21), and synthesis, for which the pattern is the "geometry of the ancients." Descartes himself stresses the importance of analysis, because of its simplicity, although both constituents are an integral part of the method (Descartes, *Disc.* II, AT VI 17). But what is important to stress is that the ideal of such a method is *mathematics* (Descartes, *Med. Synopsis*, AT VII 13).[13]

7. The new logic.

The new logic of scientific research starts by rejecting the Aristotelian syllogistic as a bare and merely formal way of drawing conclusions that are already contained in the premises, the veracity of which is either deceptively self-evident or based on a singular act of experience, rather than following from a scientifically established theory supported by experiment. The new logic transpires primarily through the analytic method that allows for incorporating and studying empirical phenomena, and not just abstract logical propositions. In Bacon, it takes a decisively negative form of the "purification of reason" by the radical critique of previous forms of knowledge as "Idols" that prevent the humankind from making any progress in producing new knowledge (OSR 133–134; *Novum Organum*, Bk. I). Such a catharsis should give way to providing new foundations of knowledge and science. The new scientific knowledge that follows the new logic is not just deduced from pure reason: it appears from the conjunction of the rational and the empirical, of intellect and senses and is thus actively produced; it is the knowledge achieved by *doing* (OSR 104). The Cartesian method only further codifies the same intention to establish a new science-oriented logic, which is then rendered fully scientific as a *mathematical* method in Leibniz and Newton.

Because this new knowledge comes from a joint effort of reason and senses, where senses are directed by reason and reason is corrected by the senses, the empirical attitude toward the known undergoes a radical—revolutionary—change. The observation of nature yields to experiment, which already in Galileo and Bacon becomes an interrogation, coercion or even torture, which puts nature under stress, in the conditions under which it is not normally seen but in which it starts confessing to what it usually does not do or say (OSR 61, 101–103, 123). Therefore, a scientist *already* needs to know, at least implicitly, what is meaningful to do and ask in order to extract knowledge from nature. In other words, we need either an explicitly or implicitly formulated program or "concept formation" (OSR 63) that would function as a theoretical framework allowing for new knowledge.

This new theoretical framework, however, is not a matter of arbitrary choice, because the study of nature is ultimately defined by how nature is and by what our reason is capable of knowing about

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[13] Cf. Jonas: "Geometers have always known that one deals with such complexity which the mind cannot directly and immediately handle, and how one deals with this is to reduce it to the simpler. …Any example of the reduction of a geometrical problem to such simple axioms and axiomatic entities as the straight line, angles, length, etc., is an example for the kind of method Descartes applies to the analysis of reality as a whole." (OSR 157).

it. In other words, we need a new understanding of *being* that would allow for a new knowledge of nature. For Jonas, the new ontology remains implicit and not fully spelled out in most of the thinkers he discusses, and only in Descartes does it become "clear and distinct," that is, explicitly and unambiguously formulated. In other words, a new ontology defines the new science: "I speak of an ontological revolution underlying and accompanying the scientific revolution" (OSR 128). We must be able to think ontological shifts and changes in order to, and prior to, being able to think the changes in our understanding of the world.

If the ontological revolution is Cartesian, then it is primarily the change in the understanding of the self as a thinking self and its thoughts (especially those that are clear and distinct) that allows for the new picture of the world as the other of the thinking self. While Bacon does the work of cleaning the field for the new science, the new ontology in its positive formulation is provided by Descartes. Rejecting the scholastic Aristotelian understanding of substance as a concrete *this*, *tode ti*, which logically can only be in the position of the subject and never that of the predicate, Descartes rethinks the notion of substance as (1) uniquely and unambiguously characterized by its single essential attribute, (2) divided into finite and infinite, and (3) produced in its very concept by the finite thinking substance (*Med.* III, AT VII 44-45). That substance now, under the Cartesian framework, does not refer to an existing thing but is constituted in its concept by thinking, is itself a fundamental turn in modern ontology. The external world, whose independent existence is also ascertained by Descartes from within thinking (*Med.* VI, AT VII 71-90), turns out to be the real other of thought. In this way, the whole of the existing reality is split into two different mutually independent (possibly depending in their existence on the infinite substance), *complementary* and *exclusive* substances of thought and matter, *res cogitans* and *res extensa*, where the former studies both itself (in philosophy) and its other (in science).

Thus, the modern split between the subject and the world is established by the subject, who in this very act also establishes itself as autonomous. The studied and understood world, which is the realm of science, is now marked and defined by dualisms: of mind and body, thought and thinking, mind and will, the internal and the external, the science of the mind and the science of nature, and the later Kantian distinction between the transcendental ego and the phenomenal world (OSR 108-109, 151-152, 154, 162, 195). As Jonas puts it, "Because clear and distinct attribution of the essential attribute to one side means at the same time denial of the other attribute to it. This mutual exclusiveness of the attributes of extension and thought is somehow the radical, logical premise for an unimpeded application of the new science to its own domain, the domain of nature as a whole. Nature is reinterpreted as being external nature, *res extensa*, and nothing else. Never before has such a conception of nature been conceived. The previous development moved towards it, but it was Descartes who made this into a new general doctrine of the nature of things as created by God" (OSR 164; cf. 154, 161, 165, 196-197). Even the simultaneous complementarity *and* exclusion of the two substances is itself a dualism!

8. Mathematization.

As Jonas rightly points out, one of the central features of the ontological and scientific revolutions is the mathematization of the world, to which he constantly comes back in his lectures (OSR 11,

59, 128, 167 et passim). Mathematization means not only the acceptance of the underlying structures of the cosmos as mathematical, proportional and beautiful, as they are perceived by the Pythagoreans and Plato but also by Kepler and Galileo, but rather that the world is describable in its *transformations* and *changes* by mathematical means. The new physic-mathematical approach, then, further implies the exclusion of occult qualities and final causes (OSR 167) as not quantifiable, and thus the reduction of the qualitative (which was the physical for Aristotle) to the quantitative (OSR 77, 156-158).

The mathematization of the world thus means not only that we see the mathematical objects in and behind natural phenomena or that the book of nature is written, as Galileo famously says, in the language of mathematics of which the words are lines, triangles, and circles (OSR 26).[14] It much more means that we should be able to formulate the very *laws of nature* as mathematically describable *laws of motion*, as Newton does (OSR 171 sqq.). The presuppositions behind, or the conditions of the possibility of, this new scientific mathematical description are, first, that only *locomotion* is considered as motion, and not just any change, which *kinēsis* encompassed for Aristotle (*Phys*. 224a21 sqq.).[15] And second, that *any* motion of *any* body—either cosmic or "sublunar, " up there of down here—can be described by such laws, by the same method and mathematical procedure. This had never been possible in ancient physics, which separated being from becoming or change, and therefore refused to apply mathematics to the study of ever-fluent things.

As a motion through the uniform *res extensa* considered as three-dimensional homogeneous Euclidean space (OSR 171),[16] locomotion is best represented by the elementary act of drawing an imaginary line (OSR 159).[17] For modern science, including Galileo, Descartes, and Newton, the construction or drawing of such a line is best described not geometrically, as ancient mathematicians describe it, but algebraically, by establishing a purely *functional* relationship between two sets (of spatial locations and temporary moments). New mathematics is thus based on the concept of relation, rather than of non-relational substance, which is now reserved to characterize both the knowing mind and the known medium in which the motion takes place. This is, in Jonas' words, "[t]he difference between what is something entirely by itself [substance] and what is added to it… by relations" (OSR 175–176). Indeed, substances are qualitative; only relations can be quantified. The new physically oriented mathematics thus allows for the description of quantities as related to each other not as substantial units but in the process of their change, or in motion.

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[14] Galileo. Assayer. In: Discoveries and Opinions of Galileo Galilei. Trans. with an Introduction and Notes by Stillman Drake. Garden City: Doubleday, 1957, p. 237-238.

[15] Cf.: Hans Jonas. "Antiker und moderner Sinn einer Mathematiker der Natur." In: "Ist Gott ein Mathematiker?" Kritische Gesamtausgabe der Werke von Hans Jonas. Philosophische Hauptwerke (KGA). Bd. I/1. Organismus und Freieit. Philosophie des Lebens und Ethik der Lebenswissenschaften. Ed. Horst Gronke. Freiburg-Berlin-Wien: Rombach, 2010, p. 125-187; p. 128–135.

[16] "By 'extension' we mean whatever has length, breadth and depth, leaving aside the question whether it is a real body or merely a space." Descartes. Reg. XIV, AT X 442. Cf.: "Space equals that which Euclidean geometry applies to, or which satisfies descriptions of such geometry" (OSR 75).

[17] See: D. Nikulin. Matter, Imagination and Geometry, Ontology, Natural Philosophy and Mathematics in Plotinus, Proclus and Descartes. Aldershot: Ashgate, 2002, p. 210-230.

For this reason, "A *law of nature is* a *certain correlation of measurable quantities*" (OSR 35).[18] The preference of algebra and functional analysis to geometry and substantial description, the rethinking of geometry as algebraic, thus constitutes an important premise that makes the mathematical formulation of kinematics possible.[19]

9. The simplicity and precision of mathematics.

In Jonas' reconstruction of new ontology and science, Descartes establishes mathematics as the model for certainty in the cognition of the world. Despite the split between the two substances, which Jonas takes to be the decisive ontological moment of the scientific revolution, both should be clearly and distinctly known, which means that "the truth of reality lends itself, or corresponds, to rational knowledge, that rationality does apprehend the true nature of things. … reality is rational in its ultimate constitution" (OSR 146–147).[20] Therefore, both mind and nature as the substantial constituents of reality should be known essentially in the same way. And if the mind's knowledge is arranged according to the method that is modeled on mathematics, then nature too should be known mathematically. This is why-"Descartes wants to transform all knowledge into mathematical knowledge, but… he wants to learn from mathematical knowledge something for his universal method: some *formal* procedure" (OSR 145).

The exemplary advantage of mathematics consists in the *simplicity* and *precision* of the knowledge it provides. For modern science, mathematics becomes the appropriate method of studying nature, because nature is itself *simple* in its foundations, even if it appears complex in its phenomena. For this reason, as Jonas says, "Nature does everything in the simplest way and behaves so that the mathematical reconstruction will fit nature" (OSR 74).[21] And thus, "The simplicity of nature is equivalent to its mathematical form. The simplicity and mathematics have a certain relation to each other. Mathematics can be complex, but the mathematical solution to a problem is always the simplest" (OSR 63). It is on the basis of simple mathematical concepts, elements, principles, and rules of deduction that the new science, beginning with Galileo, is capable of constructing scientific explanations of complex natural processes.

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[18] Thus, Galileo understands velocity as a "simple relation of time and space" Jonas (OSR 64).

[19] See: R. Descartes. La Geometrie. AT VI 367-485 and E. Cassirer. Substance and Function. Trans. W.C. Swabey and M. Collins. New York: Dover, 1953.

[20] In Jonas' account: "Only that is true knowledge which is absolutely certain knowledge. Absolutely certain knowledge I can have only of that of which I have clear and distinct perception. Clear and distinct perception I can have only of the ultimately simple ideas which I find in my consciousness. Unless it is only a derivative part of reality that plays the game, as it were, i.e., satisfies this requirement that it corresponds to the clearly and distinctly perceived ideas—if it were only a marginal, insignificant slice of reality which lives up to this requirement, then I would be left with a body of knowledge that is certain, which fulfills the requirement of certainty, but which would not fulfill another vital requirement of knowledge, namely, that it is knowledge of the world. But this cannot be, because then we would not have knowledge. Therefore, that which satisfies the requirement of certain knowledge also satisfies another requirement, namely, to be the element of all reality." (OSR 146–147).

[21] "If nature is essentially mathematical, then every true statement about nature must be in mathematical, i. e., non-qualitative, terms." Jonas (OSR 75).

Mathematics is an—or even *the*—expression of the way two independent substances, mind and matter, are and the way they can be known. The mind is mathematical because it thinks simply and precisely in terms and concepts that can be easily arranged mathematically by the mind's self-prescribed and self-extracted method. And matter is mathematical, since it is equally simple and for this reason can be considered ordered mathematical Euclidean extension. Both mind and matter (or nature) are, as it were, already co-mathematical. Mathematics permeates both the mind and the world, yet the relation between the two is asymmetrical, since the one knows itself reflectively, and the other is known by its other. For this reason, mathematics can be considered by the mathematical mind not only as descriptive of the way things are but also as prescriptive: by looking at things scientifically, the mind *must* already see them as mathematical, as reflecting the same patterns and structures that the mind finds in itself. The mathematics of the mind is disguised as the method, and the mathematics of the world appears as the laws of the ordered physical world. Since the science of modernity is primarily physics that studies motion, then, as Jonas puts it, "the *ideal* mathematical *form* of movements is the *reason for* the movements to be that way. … [T]he mathematical *form* is *not only* the *result*. It is itself the *cause* of the working, the function, of the system" (OSR 34–35). Mathematics, therefore, becomes the conceptual framework that allows Galileo and Newton to understand and mathematically formulate the laws of physical motion and the general mechanics of nature and, on the basis of this understanding, stage meaningful experiments that discover new truths about nature (cf. OSR 71, 81, 122, 177).

10. The source of the mathematization of the world.

A major question here is why does it become possible to describe and study the world mathematically, both at macro- and micro-level? If the world is essentially mathematical as is our thought, and both are independent of each other, where does this affinity come from? The mathematization of the world in its entirety was unthinkable in ancient science, where only the celestial—the divine—could be considered embodying the mathematical order. The question of the possibility of mathematical physics is rarely discussed in modern science, which almost takes it for granted that we live in a world that has already been measured and mathematized, and we simply see it this way.[22] The ontological and scientific revolution results in a new world, in which revolution itself becomes an integral part and thus does not recognize its view of the new nature as "unnatural" (OSR 196). Only a close look at non-modern science allows us to recognize that our modern view of nature as intrinsically mathematical is not immediately self-evident.[23]

If the Cartesian ontology indeed underlies the scientific revolution, then the source of the possibility of understanding the world as mathematical should be either in the knower or in the

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[22] D. Nikulin. Matter, Imagination and Geometry, p. ix-xiii.

[23] Cf. Alexandre Koyré. From the Closed World to the Infinite Universe. Baltimore: The Johns Hopkins University Press, 1957. See also: Hans Blumenberg. The Genesis of the Copernican World. Trans. R.M. Wallace. Cambridge (Mass.): MIT Press, 1989 (orig. publ. as: Die Genesis der kopernikanischen Welt. Frankfurt am Main: Suhrkamp, 1975).

known. In other words, the mathematical mind should either recognize the world as (co-) mathematical—or impose itself onto the world, thus making it mathematical. The *constructivist* position, which suggests that there is nothing mathematical in the world until we intentionally or unwittingly see it as such, is famously defended by Kant (*KrV* B 20 sqq.; cf. OSR 171, 194–195). Yet for Descartes the mathematical structure of the world cannot be instituted by thought or constructed into the world, since it contradicts the mutual independence of the two finite substances.

The *realist* position, on the contrary, takes the world as *already* mathematical. Such a world is considered by most thinkers of the scientific revolution, including Kepler, Descartes, Leibniz, and Newton, as created or produced by the infinite maker. In this light, the early modern realist position becomes a version of constructivism, where the source of the production of the world as mathematical is not the finite human mind but rather the infinite divine one. For Kepler, as Jonas argues, "The form of things is the cause of things" (OSR 38), and this form is simple, beautiful and mathematical, and originates in the divine mind. The divine mind is mathematical already in the *Timaeus* (31b–36d), although there it establishes mathematical structures only as the foundation for the cosmos as a whole and its celestial motion, not reaching down to particular transformations. The modern divine mathematician, on the contrary, is the infinite thinking substance that supports the two finite substances by continuously and momentarily supporting or recreating them (OSR 172).[24] God as a mathematician makes sure that when we think correctly, we think mathematically, and that the world is mathematical not only in its overall structure but also in all its transformations, changes, and motions. In Jonas' words,

> It is because in God's mind mathematical harmonies were established as the true plan, the constitutive of creation, that creation exhibits these features. In other words, the intelligibility which is not a plain one but a very subtle one, requiring the utter sophistication which Kepler had to master in order to discover these laws,—this subtle sophisticated mathematical structure of things is itself of a mind origin. It originates in a [divine] mind and in the human mind it comes, as it were, to recognition. The physical evidence therefore is intermediate between the intelligible, intellectual cause of things and the intellectual recipient in man. Thus man, the human mind, in discovering laws has not discovered something strange to man, but something which is, in his own originative principle or source, of a mind-like nature. (OSR 34–35; cf. 191–193, with reference to Newton)

Jonas recognizes the importance of the Judaeo-Christian heritage for the rise of the new science, with its emphasis on the primacy of the infinite and of the will. Nonetheless, this theological heritage alone cannot explain the scientific revolution, which needs additional factors to become actual (OSR 125-127).[25] However, the possibility that the intrinsic mathematization of the world is

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[24] Descartes. Le monde VII, AT XI 37; Letter to Hyperaspistes, August 1651, AT III 429.

[25] See: H. Jonas. "Jewish and Christian Elements in Philosophy: Their Share in the Emergence of the Modern Mind." In: Philosophical Essays: From Ancient Creed to Technological Man. Chicago: Chicago University Press, 1980 (first publ. Englewood Cliffs: Prentice Hall, 1974), p. 21-44 (orig. publ. as: "Jewish and Christian Elements in the Western Philosophical Tradition." Commentary 44 (1967), p. 61-68).

of divine origin is *not* an option for Jonas. In "Is God a Mathematician?," he explicitly rejects the hypothesis that God is a mathematician and the designer of a precisely calculable universe. On his account, such a god would not be able to understand and account for life, given its "inwardness" and purposiveness. Modern mathematical physics is unable to explain the phenomenon of the organism, because the new science excludes final causality, whereas for Jonas "there is no organism without teleology."[26] In other words, where life and the organism begin, mathematics stops. For this reason, the soul for Descartes is only the thinking ego, and *not* the principle of life (OSR 163). The remarkable success of modern science in the explanation of the motion of physical bodies nevertheless stops short of explaining life in the same mathematico-mechanical terms. Despite the considerable interest in biology, which starts with Descartes and Leibniz, modern science failed to apply the same mathematical program to the account for life.[27] But for Jonas it is life that becomes the fundamental phenomenon that he addresses in his philosophical and ethical program.[28]

Jonas rejects the constructivist account in favor of the realist position, which he considers in more detail in the *Phenomenon of Life*,[29] while at the same time rejecting the hypothesis that God is the source of the mathematization of the world. And yet, Jonas *does not have an explanation* for the mathematization of the world. This is indeed a major and most vexing question, to which Jonas does not provide an answer. For him, in the last instance, "It was *the fortunate coincidence* that *the first great object on which the new science* tried *itself* was indeed *such* an object that *exhibited these clean, clear mathematical characteristics*" (OSR 33). In other words, the wonder of the new mathematical science is *unexplainable*.[30]

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[26] H. Jonas. "Is God a Mathematician?" In: The Phenomenon of Life, p. 64-98; p. 91. Cf. H. Jonas. "The Burden and Blessing of Mortality." The Hastings Center Report 22 (1992), p. 34-40 and H. Jonas. "The Unanswered Question. Some Thoughts on Science, Atheism, and the Notion of God." In: Hans Jonas. La domanda senza risposta. Alcune riflessioni su scienza, ateismo e la nozione di Dio. Ed. E. Spinelli. Genova: Il Nuovo Melangolo, 2001.

[27] Descartes' approach to life is mechanistic and eventually fails to explain the organism as merely a machine, whereas Leibniz' is based on the idea of the gradation and genealogy of life as an all-pervasive yet not a mathematical phenomenon, which is probably why Leibniz is conspicuously missing in Jonas' lectures. Cf. H. Jonas. "Philosophical Aspects of Darwinism." In: Phenomenon of Life, p. 38-63; p. 53-58.

[28] H. Jonas. The Imperative of Responsibility and KGA I/1. See also: D. Nikulin. "Reconsidering Responsibility: Hans Jonas's Imperative for a New Ethics." Graduate Faculty Philosophy Journal, 23 (2001), p. 99-118.

[29] H. Jonas. "The Nobility of Sight: A Study in the Phenomenology of the Senses." In: Phenomenon of Life, p. 135-156 et passim.

[30] Says Jonas: "I have never been able to answer for myself in a satisfactory way, what made it that in that moment such an improbable thing as modern science arose? … Certainly there is no satisfactory philosophy of why the book of nature should be written in mathematical symbols, why certain assumptions had an overwhelming convincingness—they had it for him [Galileo]—fortunately. But, for instance, to conceive of motion as he did is by no means a very plausible thing. There is the fact that nobody before had viewed motion in these terms. So, in my opinion, there is a certain unresolved residue there where all our explanations fall short." (OSR 127-128).

11. The imprecision of physical bodies vs. the precision of mathematical objects.

One of the difficulties the new science faces is the problem of exactitude or precision: while mathematical objects and calculations are precise, the physical phenomena—the bodies in their dimensions, forms, and motions—are not. In his lectures, Jonas does not directly address the problem of the incongruity between the precision and simplicity of mathematics and the imprecision of physical phenomena that are nevertheless described mathematically. This discrepancy might be caused either (a) by the inability of the mathematical approach to describe the physical reality at the microlevel, which, as we think now, might behave differently, in which case there would be no real identity of the laws of motion "up there" and "down here" (in the elementary particles). Yet even quantum mechanics is subject to mathematics, although, unlike classical mechanics, it deals with probabilistic distributions. In fact, the germ of this approach was developed already by Pascal but was not used in the scientific revolution for the description of motion of bodies that was considered strictly deterministic.

Or (b) the mathematical explanation and description of physical things is in fact precise, but the physical phenomena themselves are imprecise and cannot be strictly measured or mathematically described. In each case, then, we would only have to work with mathematical approximation and idealization. Descartes is well aware of this problem, for he recognizes in the *Geometry* an insuperable gap between perfect geometrical figures and never precisely measurable and always irregular physical bodies, which these figures are meant to describe and represent.[31] In this case, the physical phenomena either cannot be really explained mathematically, or they only *appear* imprecise.

Jonas clearly sides with the latter option, assuming that historically the dichotomy between true (mathematical) essences and sensible (physical) appearances is already established in Kepler. In this case, if the truth of things is mathematical, then it should be only thinkable and thus hidden from immediate perception. Therefore, by means of mathematics, thinking discovers quantities that represent the true (hidden and only thinkable) essence of things, whereas sense-perception discovers qualities that constitute their appearance, which is "the symbols or the signs" of things (OSR 36).[32] This is exactly what modern science does: it translates the qualitative sensible physical differences into thinkable quantitative mathematical descriptions, and then retranslates them back into the qualitative, which is then located in the mathematically measured materiality.[33] The novel

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[31] As Descartes explains, "For although we cannot include in Geometry any lines that are like cords—that is to say, sometimes straight and sometimes—because the ratios between straight and curved lines are unknown, and even, I believe, unknowable to men, so that we cannot thereby reach any exact and assured conclusions: nevertheless, because we use cords in these constructions only to determine straight lines whose length we know exactly, we must not entirely reject them." Descartes. Geometry II, AT VI 412.

[32] Cf.: "[T]o know the real meaning of a quality means to reduce it to quantitative facts" (OSR 77).

[33] "Because in our external representations we can discern certain features which are clear and distinct, therefore they are more than mere thoughts of our thinking. They must be veridical. What is clearly and distinctly perceived has been reinstated as true, i.e., the extensional properties of the external world. And the non-clear and non-distinct parts are substitutes for the clearly and distinctly perceivable, i.e., for the extensional quantities, and the business of science is to

Cartesian world is the world of extension, and its imperfection is only a visible, phenomenal one: it is the imperfection of the *translation* of the extended things by the senses into the language of qualities. According to Jonas, for Galileo

> qualities are subjective… and the objective nature of nature is what is mathematically and quantitatively formulable. Now, since the reality of qualities cannot be denied, that means that what has its seat in man is of a different kind from that which has its seat in the external world. …we must make that distinction between the subjective nature of certain of our phenomena and the objective nature of others where the nature of things is adequately represented. (OSR 128; cf. 90)

While primary qualities still belong to nature, which is extended and mathematical, secondary qualities are produced by sense-perception, which is thus in Jonas' account ultimately responsible for the incongruity between mathematical precision and perceptible inexactitude.[34] In other words, it is *we* who make an inevitable misjudgement or mistake in the perception of the pure geometry of the world. For the new science, therefore, the essences are mathematical, thinkable and precise, while appearances are physical, sensible and imprecise.

12. Criticism.

Thus, Jonas' two major claims are, first, that the ontological revolution is the condition of the possibility for the scientific revolution, because the ontological framework allows us to see the world differently and anew, as well to ask questions and stage the experiments that did not make sense and were not possible before. And second, it is Descartes who most clearly expresses this new ontology, which presupposes a split—both the opposition *and* complementarity—between the thinking, the mental, "subjective", "inner" or the knower—and the extended, the physical, "objective", "outer" or the known. And in these two substances, it is their co-substantial simplicity and clarity that become fundamental for the new knowledge or science, which then can be expressed in strict mathematical terms.

There is a major problem with this approach, though, which Jonas detects but does not have ultimately an answer to: how and why is the simultaneous mathematization of the world and the mind possible? It is important to note that the modern Cartesian dualistic rupture does not allow for anything ontologically intermediate or mediating between the mind and the world. Yet, in ancient Platonic science (in Plato, Iamblichus, and Proclus), mathematical objects were distributed through various ontological realms and studied by various cognitive faculties. Thus, arithmetic examined numbers, which were distinguished into the ideal numbers identical with the forms—and into mathematical numbers identified with their logical representations. Geometry, on the other hand, studied figures that belonged to a different realm of being, intermediate between the ideal or purely thinkable and the physical. While numbers were in the province of reason (ideal

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retranslate what the senses have first translated from terms of extension into terms of quality back into terms of extension, and that has been the program of science from Descartes' time to this day" (OSR 159).

[34] "The person observing creates the qualities. Secondary qualities are produced in the act of perception" (OSR 76).

numbers were though by the non-discursive intellect-*nous*, and mathematical by the discursive reasoning-*dianoia*), and bodies were subject to sense-perception (*aisthēsis*), geometrical figures are known and produced by imagination (*phantasia*). On this interpretation, geometrical objects are both distinct from the ideal and physical entities (from the former—in that they are divisible, from the latter—in that they are unchangeable) *and*, at the same time, have something in common with both of them (with ideal objects—precision and unchangeable properties, with physical bodies—extension as represented in the imagination). In this way, both the geometrical objects and their corresponding mental faculty of imagination were *intermediate* (*metaxy*) between the thinkable and the sensible, which they both mediated *and* separated.[35]

The radicalism of the modern Cartesian ontological revolution consists precisely in the expulsion of the intermediate from both ontology and cognition, which was an inadvertent yet necessary consequence of the rigid ontological split between two finite substances. Being mutually exclusive and complementary, they do not need, and do not allow for, mediation. Thereby, the intermediate is eliminated. Besides, in the Platonic understanding of the order of being, the soul, which was the principle of life, was also intermediate between the ideal and the physical. But when the new ontology identifies the mind with abstract thinking modeled on mathematics and posits the essence of nature in geometry (OSR 170), it becomes unable to account for life and the complexity and functioning of organism. The new scientific world has no purpose (because the final cause has be expurgated) and no life (which has been identified with abstract mathematical thinking).

One of the consequences of the Cartesian ontological split is the suppression of the whole realm of intermediate entities, which in antiquity were associated with extended yet perfect geometrical figures, both thinkable and imaginable. This move enables not only the dichotomy of two complementary substances but also the *imposition* of one (geometrical as thinkable) onto the other (physical as extended and now also geometrical), as well as the identification of the thinkable non-extended numbers with the extended geometrical objects through the introduction of the system of coordinates. The physical, then, is substituted by the geometrical, which is then studied and described formally—algebraically and functionally. The identification or non-distinction of discrete numbers and continuous magnitudes, carefully differentiated in ancient science, particularly by Aristotle (*Phys*. 207b1-27, 232a23-25), becomes the major presupposition for the possibility of the scientific cognition of the world. The physical, reduced to simple magnitudes and forces (cf. OSR 73), is now seen, studied and reduced to the geometrical. In this way, the new scientific world is *already* unwittingly built as mathematical.

Yet, Descartes is unable to explain why geometrical figures are precise, whereas physical bodies, represented by geometrical objects, are not.[36] For he cannot properly locate the mathematical *qua* geometrical objects: they have to belong *both* to the *res extensa* (as extended) *and* to the *res cogitans* (as precise and thinkable), which, however, are mutually exclusive. Because he expels the intermediate, Descartes is unable to give a satisfactory answer where the mathematical (geometrical) properly

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[35] D. Nikulin. "Imagination and Mathematics in Proclus," Ancient Philosophy 28 (2008), p. 153-172.

[36] Descartes. Fifth Set of Replies, AT VII 385. Cf. D. Nikulin. Matter, Imagination and Geometry, p. 117-120.

belongs: in the physical, bodily and extended—or in the mental, thinkable and not extended. Therefore, the Cartesian attempt to think things clearly fails at its very foundational moment. The incapacity to explain the ontological status of geometrical objects becomes emblematic of modern science's inability to account for the mathematization of the new world in terms of non-theological realism, and to further explain why in the last instance we are actually able to see and study the world as mathematical.