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The Metaphysics of Cartesian Science

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Abstract: The argument of this paper is that the rationale, potential and limits of modern science are evident in Descartes, and in respect of its basic Cartesian features are still valid today. Its rationale is objectivity, its potential is a great improvement in human living conditions, and its limit is that, due to its striving for objectivity, modern science cannot in principle encompass human thought and action. Cartesian dualism is therefore well grounded, and can be elaborated on without any commitment to two autonomous types of substances.

Keywords:

Descartes;
methodological scepticism;
modern science;
res cogitans;
res extensa

1. The Objectivity of Modern Science

In his **Discours de la méthode,** [1] Descartes famously stresses the utility of modern science: it enables us to "nous rendre comme maîtres et possesseurs de la nature", that is, to turn us into masters and owners of nature. [2] By "nature", Descartes means in the first place human nature: namely, the improvement of medicine, in order to fight lethal diseases, through scientific study of the human body. After that comes improving human living conditions through technological progress achieved on the basis of the scientific study of the physical environment. Indeed, this aim was well taken, given the situation in the seventeenth century: the plague killed large parts of the population in Europe. By far the largest part of

[1] See René Descartes, **Discours de la méthode**, Jean Maire, Leyden 1637.

[2] René Descartes, **Œuvres de Descartes. Volume 6. Publié par Charles Adam et Paul Tannery**, Cerf, Paris 1902, section 6, p. 62.

the workforce was employed in agriculture in order to secure the daily survival of the people. Against that background, it is obvious that modern science paved the way for an enormous success in respect of the improvement of human life.

How did modern science make this success possible? In this paper, I first sketch out how Cartesian science achieves objectivity (this section and the next one) and then briefly go into the development of modern science beyond Descartes. [3] The focus of the second half of the paper then consists in elaborating on the argument as to why Cartesian science meets a principled limit in human thought and action. [4] I conclude with a brief assessment of Cartesian dualism. [5] The rationale of this paper is thus not to give an exegesis of Descartes's texts. Its aim is to offer an assessment of the science for which Descartes laid the foundation, both in his scientific and in his metaphysical work.

The key to the success of modern science is its objectivity. This means abstracting from all judgements of value. Science studies things as they are independently of attributing any value, and thus also any intrinsic goodness, to them. Modern science is thereby based on a strict separation between facts and norms. This implies also refraining from describing things in terms of intrinsic essences or forms, for these conceptualize things by imposing a norm on them.

Indeed, adopting a very broad and general perspective, we can characterize the transition from ancient and medieval science and epistemology to modern science and epistemology in the following way: ancient and medieval science and epistemology do not in general implement a principled distinction between knowledge of facts and knowledge of norms or values. Knowledge is knowledge of the intrinsic essences of things — be they transcendent, as with Platonic ideas, or immanent, as with Aristotelian forms. These essences are not only matters of fact, but also set a standard as to how things *should* be. Thus, for instance, the form or idea of a horse traces out the ideal type of a horse. Flesh and blood horses participate in that idea, or implement that form, insofar as they come close to the ideal type of a horse. But they can never match it. They are always to a certain extent deficient. [6]

[3] See Descartes, **Œuvres de Descartes...**, section 3.

[4] See Descartes, **Œuvres de Descartes...**, section 4.

[5] See Descartes, **Œuvres de Descartes...**, section 5.

This view of intrinsic essences of things that are matters of fact as well as normative then enables the conception of a hierarchy of forms that implements values and that culminates in a supreme being. In other words, the normative character of the forms makes it possible to establish a hierarchy that goes from ordinary things — such as horses — up to a supreme being. When philosophy turns Christian, the supreme being is God. God not only is the culmination point of the hierarchy of being, but also creates the world. He is not only absolutely good, but also absolutely powerful.

However, in late-medieval scholasticism, it becomes evident that there is a tension in the notion of God being absolutely powerful. His being absolutely powerful implies that He can do anything in virtue of His power (*de potentia absoluta Dei*): for instance, he could also send a saint to hell. If, by contrast, God exercises His power in an ordinary manner (*de potentia ordinata Dei*), what God does is determined by the hierarchy of forms and thus subordinated to it. A tension in the notion of absolute power is therefore evident: power as subordinated to reason is restricted. For if power is subordinated to reason, then anything that *de facto* is the result of the exercise of power can be recognized as reasonable independently of any use of power coming into play. In consequence, power manifests itself *qua* power only by bringing about things that fly in the face of reason. The possibility of God acting in virtue of His absolute power therefore calls into question whether human beings can rely on recognizing a hierarchy of forms as a guide for their thought and action. Against the background of late-medieval voluntarism and the way this stance works out the consequences of God having absolute power, one can thus regard modern science with its rejection of a hierarchy of forms that implement values and its separation between facts and norms as legitimate [7] — or dismiss it as illegitimate, if one considers the voluntarist conception of God's absolute power to be illegitimate. [8]

[6] See, e.g., Plato, **Parmenides**, trans. Mary Louise Gill and Paul Ryan, in: John M. Cooper (ed.), **Plato: Complete Works**, Hackett Publishing Co., Indianapolis 1997, 130e–133a, pp. 364–367 [359–397].

[7] See Hans Blumenberg, **The Legitimacy of The Modern Age**, trans. Robert M. Wallace, MIT Press, Cambridge — London 1983 (German original: **Die Legitimität der Neuzeit**, Suhrkamp, Frankfurt 1966).

[8] See André de Muralt, **L'enjeu de la philosophie médiévale: études thomistes, scotistes, occamiennes et grégoriennes**, Brill, Leiden 1991, chapter 2, pp. 47–89.

To stress again, modern science as conceived by Descartes is not free from purpose and values: it aims at improving the human condition by enabling medical and technological progress. However, in order to serve that aim, science has to be objective. Being objective means in the first place abstracting from all judgements about purpose and value in the things that one is considering. Insofar as things in nature — including our own bodies — are open to scientific enquiry, they are conceived as not having a purpose or a value in themselves. Being free of value in themselves, they are at the disposal of human goals. Thus, when one intervenes in the movement of things in order to change their motion to fit human purposes, one does not violate any intrinsic values or purposes of these things.

Furthermore, being objective means abstracting from all the features that are intrinsic to the human perception of the world: that is, the sensory qualities such as colours, sounds, tastes, smells and the like. These do not belong to things in nature in themselves, but to our way of gaining knowledge of them by using our senses. If one abstracts from all these features, what remains of the natural world is extension and change in extension — that is, motion. We thus arrive at the Cartesian characterization of nature, including our own bodies, as *res extensa*, extended substance. [9]

This is what the world amounts to when we have abstracted from all subjective features — that is, by approaching the (point of) view from nowhere: no qualities, only matter in motion, meaning extension and change in extension. Obviously, however, the notion of a (point of) view from nowhere is inconsistent: such a point of view would be no point of view at all. It would not be anything from which one could express knowledge claims in a human language using a semantics and a pragmatics. The ideal of the scientific viewpoint being the (point of) view from nowhere is therefore only a regulative idea, to use a Kantian term: it is something that science aspires to achieve without being able to achieve it.

Science therefore needs a methodology of scepticism: any knowledge claim has to be subject to scrutiny in order to find out whether it really expresses knowledge of objective matters of fact or is still penetrated by subjective elements rooted in the limited perspective of the person or persons formulating the knowledge claim in question. Scrutiny means not only searching for evidence that con-

[9] See René Descartes, **Principia Philosophiae**, Part Two, Elsevier, Amsterdam 1644, paragraph 4.

firms the claim in question, but also — and more importantly — determining what speaks against it and would falsify it, and then trying to find out whether there in fact is evidence that invalidates the claim in question. In short, a knowledge claim is confirmed to the extent that it resists efforts to falsify it.

2. Nature as *res extensa*

Abstracting from all qualities means recognizing position as the only basic or primitive physical parameter. There is a good reason for doing so: in the first place, when examining a knowledge claim in science, all the empirical evidence that can be obtained to confirm or invalidate the claim in question consists in observations of the positions and changes of position of discrete objects. Accordingly, all measurement outcomes are recorded as relative positions within configurations of discrete objects — such as, for instance, pointer positions or digital numbers on a screen. In this vein, the physicist John Bell famously said: "[…] in physics the only observations we must consider are position observations, if only the positions of instrument pointers". [10] The qualification "in physics" (or "in science", generally speaking) is appropriate: common sense observations typically involve colours, sounds or scents of spatially arranged objects. In common sense, the positions of objects are discerned by means of these sensory qualities. Science abstracts from the sensory qualities. What then remains are the relative positions of discrete objects and their alteration. These are correlated with the sensory qualities, in the sense that science can account for changes in sensory qualities on the basis of changes in position.

According to physics, macroscopic objects are composed of microscopic objects that ultimately are elementary particles. Consequently, if a theory describes the spatial arrangement of the particles and its change in time correctly — that is, the arrangement and evolution of fermionic matter according to contemporary physics [11] — it has got everything right that can ever be checked in scientific experiments. [12] Two theories that agree on the spatio-temporal arrangement of the

[10] John S. Bell, **Speakable and Unspeakable in Quantum Mechanics**, *Collected Papers on Quantum Philosophy*, Cambridge University Press, Cambridge 1987, p. 166.

[11] See Bell, **Speakable and Unspeakable…**, p. 175.

[12] See Tim Maudlin, **Philosophy of Physics: Quantum Theory**, Princeton University Press, Princeton 2019, pp. 49–50.

elementary particles cannot be distinguished by any empirical means, whatever else they may otherwise say and disagree on. By the same token, two possible worlds with the same spatio-temporal arrangement of the elementary particles are indiscernible by any scientific means.

This is the strongest argument for treating position as the only basic or primitive physical parameter, and thus for the natural world, insofar as it is accessible to modern science, being *res extensa* only: admitting anything else over and above positions as basic or primitive would imply treating empirically indiscernible situations or worlds as being nonetheless different in some matters of fact. Obviously, this is a generalization of Leibniz' famous argument against Newton's ontological commitment to absolute space and time: [13] the argument applies, in fact, to anything that is admitted as ontologically primitive in the scientific description of the world beyond relative positions and their alteration.

The obvious objection to this stance consists in raising the following question: positions of what? To be sure, science abstracts from all sensory qualities. However, even if all that is pertinent for scientific explanations are the relative positions of discrete objects only, and their changes, one may wonder whether there has to be more to them than relative positions for them to be the *substance* of the natural world. In other words, it seems that a *res* cannot only consist in extension in the sense of distance relations that obtain among featureless objects that, in the last resort, are not extended themselves, being merely point particles. [14] Hence, even if an intrinsic essence of objects in nature is irrelevant for and inaccessible to science, it may nevertheless have to exist for these objects to be able to do what science wants them to do: namely, to account for macroscopic phenomena as accessed through sensory qualities. And if there is no intrinsic essence of individual objects, it seems that there would still at least have to be a general stuff-like essence of matter — something more than relative positions and their alteration, in virtue of which the things in nature are *material* objects. Otherwise, if all that remains of matter is the geometry of distances between sparsely distributed point particles and changes to these distances, it would seem that their material nature

[13] See Leibniz' third letter to Clarke, in : Carl Immanuel Gerhardt (ed.), **Die philosophischen Schriften von G. W. Leibniz**, Band 7, Weidmannsche Verlagsbuchhandlung, Berlin 1890, pp. 363–364.

[14] See John Foster, **The Case for Idealism**, *International Library of Philosophy*, Routledge, London 1982, pp. 51–67.

will fade away upon inquiry. However, this concern is unfounded. There is nothing incoherent in the notion of *res extensa*.

If there is a plurality of objects, there has to be something that individuates them — that is, something that answers the question why *this* is one object, *that* another, etc., so that there really is a plurality of objects instead of just one. Furthermore, there also has to be something that unites these objects so that they make up a world. In other words, there has to be a world-making relation: that is, a relation that binds all and only those objects together that make up a world. It is evident that the distance relation fulfils the latter task: all and only those objects that are spatially related constitute a world. If there were objects not at a distance from each other, they would inhabit different worlds. If they are related by distance, they are in one and the same world. [15]

Moreover, the distance relations — and only they — individuate the objects: what distinguishes each object in a configuration of objects is the position that it has relative to all other objects. Even if a configuration is partially symmetrical, there always is at least one object in the real world outside that symmetry relative to which all the other objects can be distinguished. Thus, for example, motion can always be referred to the fixed stars as a reference system relative to which the other objects are in motion and can be distinguished by their distances.

Scientific parameters that are attributed to physical objects over and above their relative positions — such as mass or charge — cannot distinguish the latter as such: they differentiate between various kinds of particles, such as those particle species admitted in today's standard model of elementary particles. They cannot distinguish between the individual particles within a species or kind, because all the particles of a given species — such as, for instance, all electrons — have the same values in respect of mass, charge, etc. The demand for something that individuates the physical objects is fulfilled by the distance relations, and by them only. Therefore, there is no need for anything more than distance relations to both individuate the objects and have a relation that binds them together so that they constitute a world. This insight is expressed in today's metaphysics by the stance known as *ontic structural realism*, which draws support from contemporary physics. [16]

[15] See David Lewis, **On the Plurality of Worlds**, Blackwell, Oxford 1986, pp. 69–81.

Indeed, one can regard these considerations as confirming the Cartesian metaphysics of nature, and vindicating it also in the context of contemporary science: nature, insofar as it is accessible to scientific enquiry, is *res extensa.* That is to say, there is nothing more to matter than extension in the guise of distance relations — between what are, in the last resort, point particles — and their alteration. In particular, there is no stuff-like essence of matter per se. The impenetrability of matter, often invoked as a criterion for the latter, is also accounted for by the individuation of material objects through distance relations: for there to be two material objects, there has to be a distance between them, in the sense of a non-vanishing distance — consequently, if there are two objects, they cannot penetrate each other.

Against this background, Esfeld and Deckert set out to show how modern physics can be construed on the basis of a primitive ontology of matter that is defined by the following two axioms or principles:

(1) There are distance relations that individuate simple objects — namely, matter points.

(2) The matter points are permanent, with the distances between them changing. [17]

The task of physics, then, is to uncover salient patterns or regularities in the motion of matter — that is, the changing of distance relations — such that laws can be formulated that represent the motion of matter in a simple and informative manner and make it amenable to human intervention. Obviously, in order to conceive of laws of nature, more parameters are needed than just relative positions and their changes. The reason is that if a configuration of matter is characterized

[16] See James Ladyman, "What is Structural Realism?", *Studies in History and Philosophy of Modern Science* 1998, Vol. 29, No. 3, pp. 409–424, https://doi.org/10.1016/S0039-3681(98)80129-5; Steven French and James Ladyman, "Remodelling Structural Realism: Quantum Physics and The Metaphysics of Structure", *Synthese* 2003, Vol. 136, No. 1, pp. 31–56; https://doi.org/10.1023/A:1024156116636; Michael Esfeld, "Quantum Entanglement and A Metaphysics of Telations", *Studies in History and Philosophy of Modern Physics* 2004, Vol. 35, No. 4, pp. 601–617, https://doi.org/10.1016/j.shpsb.2004.04.008; Michael Esfeld and Vincent Lam, "Moderate Structural Realism About Space-Time", *Synthese* 2008, Vol. 160, No. 1, pp. 27–46, https://doi.org/10.1007/s11229-006-9076-2.

[17] Michael Esfeld and Dirk-André Deckert, **A Minimalist Ontology of The Natural World**, Routledge, New York 2017, p. 21.

only in terms of relative positions, this characterization contains nearly no information about how the configuration evolves. Taking the particles to be individuated by their relative positions puts only a few general constraints on how they move, such as ruling out their penetrating one another. Yet this is insufficient to obtain a law that would tell us how they move. Ned Hall expresses the point at issue in these terms:

> [...] the primary aim of physics — its first order business, as it were — is to account for *motions*, or more generally for change of spatial configurations of things over time. Put another way, there is one Fundamental Why-Question for physics: Why are things located where they are, when they are? In trying to answer this question, physics can of course introduce *new* physical magnitudes [...]. [18]

The new physical magnitudes or parameters are introduced in terms of the role that they play with respect to the motion of matter. Consider Newtonian gravitation: the particles are characterized not only by their relative positions and initial velocity, but also by the parameter of mass (inertial and gravitational mass, which always have the same value). In virtue of having a mass, the particles attract each other as described by the law of gravitation, modulo the gravitational constant. Given the positions, velocities and masses of the particles in the universe at a time t and the gravitational constant, their gravitational attraction at t is fixed. There is no force over and above the masses. The crucial — and sufficient — parameter for capturing the pattern of attractive, gravitational motion is mass.

There is no need to add a commitment to mass as an intrinsic property to the characterization of the particles in terms of their relative positions. It is not the case that something like intrinsic essences re-enters modern science through the backdoor, under the mantle of the dynamical parameters attributed to physical objects to capture their motion in terms relevant to the formulation of laws of motion. As Ernst Mach put it, when commenting on Newton's **Principia**, "The true definition of mass can be deduced only from the dynamical relations of bodies"; [19]

[18] Ned Hall, "Humean Reductionism About Laws of Nature". Unpublished manuscript, 2009, p. 29 [1–55], https://tiny.pl/wc7f9 [14.11.2022]. The shorter version of this article was published in: Barry Loewer and Jonathan Schaffer (eds.), **A Companion to David Lewis**, *Blackwell Companions to Philosophy*, John Wiley & Sons, Inc., Malden — Oxford — West Sussex 2015, pp. 262–277, https://doi.org/10.1002/9781118398593.ch17, [emphasis in the original].

[19] Ernst Mach, **The Science of Mechanics: A Critical and Historical Account of its Development**, trans. Thomas J. McCormack, Fourth Edition, Open Court, Chicago 1919, p. 241 (German original: **Die Mechanik in Ihrer Entwickelung Historisch-Kritisch Dargestellt**, Brockhaus, Leipzig

that is to say, mass is a parameter that expresses a dynamical relation among the physical objects. There is nothing more to mass than the role that it plays in respect of the motion of physical objects.

The same goes for all the other dynamical parameters that a physical theory conceives of in order to formulate a law of motion — such as charge, energy, fields, a wave function, etc. They are all introduced in terms of the role that they play in relation to the motion of matter as expressed in a law of motion. They can therefore all be subsumed under the label of the "dynamical structure" of a physical theory. By contrast, the basic or primitive ontology is the ultimate referent of the theory — the bedrock of the physical world, so to speak, that can no longer be characterized in terms of the role that it plays with regard to the evolution of something. These are the relative positions of point particles that are individuated by these positions and their alteration, with the changes then being accounted for by introducing further parameters relating to the role that these parameters play in respect of the evolution of the particles' positions.

Hence, there is no cogent reason to go beyond the Cartesian characterization of nature as *res extensa* when accounting for the motion of matter. Mass, charge, energy, etc., are all literally speaking *located* or *placed* in the motion of matter — to use the terms common in today's metaphysics. [20] In other words, first comes the motion of matter, as characterized in (Cartesian) terms of *res extensa* only (i.e. distances and their alteration), and then come the dynamical parameters, such as mass, charge, energy, etc., as located in the overall particle motion. Because particles move in a salient pattern of attracting each other, they have a mass. Because particles move in a salient pattern of attracting and repelling each other, they are like- or opposite-charged, etc. Mass, charge, energy, etc., are therefore not a matter of intrinsic essences or properties of physical objects that the latter have in and of themselves, over and above their standing in distance relations and any alterations to these. They are instantiated as the patterns or regularities *of* such change. Consequently, they are nothing over and above the manner in which this change actually occurs.

1897).

[20] See Frank Jackson, **From Metaphysics to Ethics: A Defence of Conceptual Analysis**, Oxford University Press, Oxford 1998, pp. 1–27; Huw Price, "Naturalism Without Representationalism", in: Mario de Caro and David Macarthur (eds.), **Naturalism in Question**, Harvard University Press, Cambridge 2004, pp. 71–88.

It seems that this way of conceptualizing the laws of nature and the dynamical structure of a physical theory gets scientific explanations upside down: science seems to explain the motion of matter by attributing parameters such as mass, charge, energy, etc., to physical objects, yet these parameters only provide for an efficient tracking of the motions that occur in the universe, enabling us to identify salient patterns such as those pertaining to gravitational or electromagnetic motion. Supposing that these parameters explain how the motion in question comes about runs into the circularity problem that Molière illustrates in his piece *Le malade imaginaire* (1673): one does not explain why people fall asleep after the consumption of opium by attributing a dormitive power to opium, because this power is *defined* in terms of the role of making people fall asleep. By the same token, one does not explain why there is attractive motion in the universe by attributing a mass to bodies, because mass is *defined* in terms of the role of making bodies attract each other.

Physics explains things through unification: one establishes that it is not astonishing that apples fall from trees in the autumn, in that this involves the same pattern of motion as the Earth turning around the Sun. That is, one explains something by showing how that which calls for explanation is part of a general pattern or regularity of motion, such as attractive motion as described by the law of gravitation. Physics has accomplished its task once it has identified the salient, universal patterns or regularities of motion. But science cannot explain why there are these patterns of motion. In short, science can retrace various apparently different motions to a universal pattern of motion such as gravitation, but it cannot explain why there is gravitation.

3. Beyond Cartesian Science

Cartesian science evinces a direct link to empirical phenomena. The connection also includes the outcome of measurements, although Descartes does not talk about measurements specifically. According to him, science abstracts from all subjective features, including the particular ways in which we perceive things through our senses (i.e. colours, sounds, smells and tastes), keeping only the relative positions of things and their alteration. [21] However, there is a direct link through the representation of positions and the account of their evolution to ob-

[21] See Descartes, **Principia Philosophiae…**, paragraph 4.

jects in the world and their changes. As was mentioned in the previous section, if a theory correctly describes the spatial arrangement of objects and their alteration, it has described everything that can ever be checked in scientific experiments and measurements. Cartesian science thus consists in geometry and kinematics. Newton then adds dynamics, through the force-related laws that he formulates in his **Philosophiae Naturalis Principia Mathematica**.[22] There is no problem with the interpretation of classical mechanics, constructed on this basis, of the sort that we encounter with quantum mechanics: it is clear what classical mechanics is referring to, and how it describes the evolution of what it is talking about, such that it thereby accounts for the experiments and measurement outcomes that serve to confirm the theory in question.

However, classical mechanics is applicable to concrete situations only if certain conditions are met. The laws that a fundamental physical theory poses are always universal laws: they apply to the configuration of matter across the *entire* universe. Consider Newtonian gravitation: given the positions, velocities and masses of the bodies in the universe at a specific time plus the gravitational constant, the law will tell us how the configuration of matter in the universe evolves with respect to gravitational motion. Generally speaking, the dynamical structure of a fundamental physical theory relates the state of the universe at one time to the state of the universe at other times.

Nonetheless, no such dynamical structure could be tested if it were not applicable also to particular objects within the universe (or if it did not, at least, contain a procedure for how to derive its application to particular objects). Consider again Newtonian gravitation: the theory says that the gravitational acceleration of any one object in the universe at any given time depends, strictly speaking, on the positions, velocities and masses of all the other objects in the universe at that time. But it formulates that dependence in mathematical terms that pertain to the correlated motion of pairs of objects.

Even so, in applying the law of gravitation to pairs of objects, one must presuppose that nothing outside the pair in question interferes with its interaction in a significant manner. In other words, one has to presume that the influence of the environment — which is the rest of the universe, in the last resort — is negligible,

[22] See Isaac Newton, **Philosophiae Naturalis Principia Mathematica**, Royal Society, London 1687, chapter entitled "Axiomata, Sive Leges Motus".

at least for all practical purposes. The satisfaction of this condition cannot be assured by the mere formulation of a physical theory. It is a substantial assumption about what the world is like, which, fortunately, is satisfied: it is usually possible to consider two bodies in isolation and abstract from the influence of the rest of the world, because this influence is insignificant, as when one calculates the trajectory of a stone falling to the ground. Furthermore, such trajectories are, fortunately, by and large insensitive to slight variations in the initial positions and velocities of these pairs of objects. That is why, in these paradigmatic cases, one can apply the Newtonian law of gravitation to make deterministic predictions about the motion of particular objects even though one does not know about all of the rest of the universe, and cannot really exactly know their initial positions and velocities.

On the other hand, the conditions for employing Newtonian gravitation to make deterministic predictions about the motions of particular bodies are in fact satisfied only in rather rare cases. If, instead of a stone, one throws a coin to the ground, one cannot predict whether it will land heads or tails: a very tiny variation in the initial position and velocity of the coin can alter the entire result, and it is practically impossible for us to know the exact initial positions and velocities. Indeed, the coin-tossing case is unfortunately the paradigmatic one. That is why Cartesian and Newtonian science — geometry, kinematics, dynamics — needs to be complemented by a statistical theory that enables us to make statistical predictions about outcome distributions given our ignorance of the exact initial conditions.

Statistical mechanics achieves this result: it tells us what the typical evolution of a system with many particles is: that is, the evolution that occurs under almost all initial conditions. Thus, for instance, the molecules of a gas will move into a state of thermic equilibrium under almost all initial conditions, a long series of coin tosses will exhibit an equal distribution of heads and tails under almost all initial conditions, and so on.

Statistical mechanics presupposes the Hamiltonian formulation of classical mechanics. This formulation introduces a mathematical space known as *phase space* in order to represent the particle configuration and its evolution; for N particles, phase space has $6N$ dimensions — three for the initial position, and three for the initial velocity of each particle. Thus, each point of $6N$-dimensional phase space represents a possible configuration of N particles in three-dimensional

physical space. The Lebesgue measure is used as the measure of probability for phase space. This then enables the formulation of statements such as that gases typically evolve towards a state of equilibrium, etc., which make predictions about the statistical distribution of outcomes possible. [23]

While this way of proceeding is key to practising physics when ignorant of the exact initial conditions involved, by operating in an abstract mathematical space one loses the direct reference to physical objects that characterizes Cartesian science. The operations in the mathematical space in question have no direct physical meaning apart from the fact of their eventually yielding statistical predictions of measurement outcome distributions that can be tested. This, then, is also the reason why quantum mechanics, in contrast to classical mechanics, faces a problem of interpretation: the theory only makes predictions of measurement outcome statistics achieved via operations in an abstract mathematical space (i.e. a configuration space, Hilbert space, or Fock space).

Indeed, we must also go beyond Cartesian science in yet another respect. There is more to natural science than physics. Physics is universal: it deals with universal patterns or regularities of motion that obtain everywhere in the universe, as far as we can judge. All the objects in the universe are physical objects. They are all subject to gravitation. However, there are also special properties and systems that emerge during the evolution of the cosmos in particular places and times — notably during the evolution occurring on Earth.

In the twentieth century, a powerful tool was developed that enables us to integrate emergent properties into Cartesian science. That tool is functionalism. Starting from configurations of basic physical objects described in terms of extension and motion, one defines everything else by means of its function in the sense of its role with respect to the evolution of these configurations; this then enables the locating of the things thus defined within configurations of basic physical objects — namely, in those ones that realize the role in question.

[23] See Dustin Lazarovici and Paula Reichert, "Typicality, Irreversibility and The Status of Macroscopic Laws", *Erkenntnis* 2015, Vol. 80, No. 4, pp. 689–716, https://doi.org/10.1007/s10670-014-9668-z.

Functionalism in this sense was set out most notably by David Lewis. [24] As was mentioned in the previous section, it applies already to dynamical physical parameters over and above the primitive parameters of extension (distances) and motion (change in distances). Thus, parameters such as mass, charge, energy, etc., are introduced in terms of the functional role that they play with respect to the motion of matter. It is significant that functionalism then applies to emergent properties.

Consider water. As we know from scientific investigation, there is no fundamental water-stuff in the world. Modern science has superseded the ancient conception of the four elements of earth, water, air and fire. Yet there is, of course, water in the world: there are things in the world that fulfil the functional role of appearing odourless and colourless, of being thirst-quenching in virtue of the change in the motion of certain parts of our bodies that they bring about. These are configurations of H_2O molecules. Thus, by defining water in terms of its thirst-quenching role — that is, its role as regards certain motions occurring in our bodies — one locates it within the scientific ontology of matter in motion (*res extensa*). Certain particle configurations, moving in certain characteristic ways, simply *are* water.

By the same token, there is no *élan vital*, in the sense of a *sui generis* life-stuff or causal power, yet there are organisms in the world. The functional role that defines what it is to be alive in terms of characteristic motions such as reproduction and adaptation to the environment is realized by certain configurations of molecules — as we have known ever since the rise of molecular biology in the twentieth century. One famous example is the discovery of the molecular composition of DNA by James Watson and Francis Crick. [25] Again, this means that certain particle configurations, moving in certain particular ways, *are* organisms. Life is thus located in certain particle configurations. There is no additional, primitive life-stuff.

[24] See David Lewis, "How to Define Theoretical Terms", *Journal of Philosophy* 1970, Vol. 67, No. 13, pp. 427–446, https://doi.org/10.2307/2023861; David Lewis, "Psychophysical and Theoretical Identifications", *Australasian Journal of Philosophy* 1972, Vol. 50, No. 3, pp. 249–258, https://doi.org/10.1080/00048407212341301.

[25] See James D. Watson and Francis H.C. Crick, "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid", *Nature* 1953, Vol. 171, No. 4356, pp. 737–738, https://doi.org/10.1038/171737a0.

Again, this is not an intrinsic affair. No particle configurations are intrinsically water, or intrinsically organisms. Certain particle configurations are water or organisms only if they are inserted in an environment with certain stable conditions — that is, certain stable regularities — such that these configurations can exercise the functional roles that define water or organisms. That environment is, strictly speaking, the whole of the rest of the universe: this condition defines normal conditions for the exercising of these functional roles in terms of nothing from the rest of the universe preventing the stable regularities in question from obtaining — such as the regularity that leads from H_2O molecules to thirst quenching motions in the body, or from certain chains of molecules to motions that are phenotypic traits of certain organisms, etc. Hence, showing how emergent features of the universe fit into the treatment of the natural world as *res extensa* only is always a global affair, even though these features are located in certain particle configurations.

Functionalism, as a method for dealing with emergent features, is in principle unlimited. In a sense, it is just a matter of definition. One can simply stipulate that everything that is not part of the primitive ontology of matter in motion be defined in terms of a functional role that it exerts for matter in motion. Thus, one can apply functionalism also to the mind, stipulating that thoughts and intentions are to be defined by certain functional roles, which in the end are functional roles for the behaviour and thus the bodily motions of persons, realized by certain neuronal configurations in the brain. One can even go as far as applying functionalism in ethics: starting from the normative, moral attitudes that people *de facto* have in a society at a certain time, one can formulate functional definitions of these attitudes that ultimately come down to definitions in terms of dispositions for behaviour — that is, what people do under certain circumstances given their attitudes. [26]

If one takes functionalism to be unlimited, one goes from science to scientism. Scientism is the view that the method of science is unlimited: it applies to all areas of being. However, the issue is whether the functional definitions, articulated in terms of a role with respect to matter in motion, are still convincing when it comes to the human mind. Here, Cartesian science encounters a principled limit that rules out also applying its method to human thought and action.

[26] See Jackson, **From Metaphysics to Ethics...**, pp. 113–162.

4. Persons as *res cogitans*

Modern science as conceived by Descartes abstracts from all subjective judgements and seeks objectivity, the (point of) view from nowhere. However, this very method implies that it cannot in principle be applied to subjective features. If the scientific viewpoint consists in abstracting from the latter in order to arrive at objectivity, then it simply follows that those same subjective features are not accessible to the scientific viewpoint.

This limitation concerns, in the first place, sense experience. The general argument, in today's metaphysics, for something along these lines can be summed up in the following way: having sense experience means having a perspective on the world, which is by definition a subjective perspective. A being that has sense experience is not merely an object that moves according to certain patterns of motion: rather, it has a subjective perception and feeling of what it is like to be in the world, having certain qualitative experiences. To be sure, Cartesian science can discover sufficient physiological conditions for having sense experience, and the content of the experience may supervene on certain brain states, given certain conditions in the environment. Nevertheless, it is not the case that the brain states in question realize the experience in the sense that the sensory qualities could be captured by means of a functional definition of the role they play with respect to the behaviour of the organism that is such that certain physiological states of the organism *are* sensory experiences. Such a functional definition misses the qualitative character of the experience, the subjective perspective on the world. It cannot account for what it is like to see colours, taste cheese, smell smoke, jump for joy, etc. Accordingly, the issue of how to account for subjective experience has come to be known as the "hard problem of consciousness". [27]

Subjective experience pertains to many higher-level animals. Thought and action — which, as far as we know, characterize only humans — presuppose a subjective perspective on the world, and thus experience, but are still categorically different from it. The reason is that with thought and action normativity comes into play. It makes no sense to ask for a justification for the behaviour of animals that have subjective experience. When a cat frightens a mouse before catching and eating it, it would be pointless to morally condemn the behaviour of the cat, for

[27] See David J. Chalmers, **The Conscious Mind: In Search of a Fundamental Theory**, Oxford University Press, Oxford 1996.

this is merely the instinctive behaviour of cats. By contrast, in the case of humans, it does make sense to ask for a justification, as humans are not simply subject to their sense impressions, desires and needs, but have the ability to position themselves with respect to them.

The obvious argument against human thought and action being accessible to the method of Cartesian science is that in the case of these, the issue is not what the objective facts are, but how human subjects assess them in forming beliefs and intentions for action. This is, most notably, the argument against scientism of Friedrich von Hayek and Karl Popper: [28] when it comes to human thought and action, everything that science abstracts from is of central importance. The obvious counterargument is that what humans think and do is open to scientific investigation, too: it is possible to describe objectively what the thoughts and intentions of a human subject — or a group or a population of human subjects — are.

However, thoughts and intentions are not open to scientific investigation from the standpoint of the view from nowhere. From that point of view, there is neither sense experience in the world, nor thought and action. In order to have the realization that a being has sense experience, and to understand the qualitative character of its experience, one has to take one's own sense experience as a basis and attribute qualitative experience to other beings by analogy with one's own — that is, one can precisely not abstract from one's own subjective perspective. Propositions about the experience of other beings will be objective, then, in the sense that they will be true or false depending on what the experience of these other beings is; but conceiving of such propositions presupposes one's not abstracting from one's subjective perspective.

When it comes to understanding the thoughts and intentions of humans, the adoption of a normative attitude towards them is called for: that is, the attitude that consists in realizing that behaviour that expresses thoughts and actions is subject to being assessed as correct or incorrect. This is not possible if one just adopts a third-person perspective towards this behaviour; rather, it only becomes so by linking it up with one's own thoughts and actions — that is, by adopting a first-person perspective. Propositions about the thoughts and intentions of

[28] See Friedrich August von Hayek, **The Counter-Revolution of Science: Studies on The Abuse of Reason**, Free Press, Glencoe 1952; Karl R. Popper, **The Poverty of Historicism**, Routledge, London 1957.

other humans formulated from that perspective can then count as objective, in the sense that they are true or false depending on what the thoughts and intentions of the humans in question (present or past) are (or were); but, again, any such conceiving of such propositions presupposes our not abstracting from the subjective, first-person perspective.

The upshot of these considerations is a *transcendental argument* about the human mind. A transcendental argument is concerned with necessary conditions for the possibility of something. More precisely, it is about conditions whose denial would amount to a performative contradiction: the performance of the denial of these conditions would in fact be an act that exemplifies these conditions. Accordingly, a transcendental argument is an *a priori* argument. It cannot be invalidated by experience, since its content is not touched by empirical facts. A transcendental argument can only be wrong through committing a logical error: one can take something to be a performative contradiction without there being any such contradiction in respect of the purported facts.

Descartes formulates a transcendental argument in the second of his **Meditationes de prima philosophia**. [29] The thinking mind exists because denying that one thinks would be a performative contradiction — a performance of the act of thinking in denial. However, Descartes then neglects the point at issue in thought (or *logos*): namely, its being subject to justification (*logon didonai*).

Immanuel Kant elaborates on a transcendental argument in that respect. He says, in the:

> If an appearance is given to us, we are still completely free as to how we want to judge things from it. [30]

That is to say, appearances — sensory impressions — do not impose thoughts on persons. A being forms beliefs if and only if she has the capacity to position herself with respect to sensory impressions and to make up her mind by thinking about reasons for her beliefs. That is how normative attitudes come into play:

[29] See René Descartes, **Meditationes de prima philosophia,** Soly, Paris 1641.

[30] Immanuel Kant, "Prolegomena to Any Future Metaphysics that will be Able to Come Forward as Science", trans. Gary Hatfield, in: Henry Allison and Peter Heath (eds.), **Theoretical Philosophy After 1781**, trans. Gary Hatfield, Michael Friedman, Henry Allison, and Peter Heath, *The Cambridge Edition of The Works of Immanuel Kant*, Vol. 3, Cambridge University Press, Cambridge 2002, paragraph 13, note III, p. 85 [29–170].

a person grants something the status of being a reason for a thought or an action by taking it to be correct or incorrect in relation to the situation at hand and thus being subject to justification. Consequently, reason (*logos*), freedom and normativity are intertwined.

Consider how John McDowell describes what it would take for a wolf to entertain beliefs:

> A rational wolf would be able to let his mind roam over possibilities of behaviour other than what comes naturally to wolves. [...] [This] reflects a deep connection between reason and freedom: we cannot make sense of a creature's acquiring reason unless it has genuinely alternative possibilities of action, over which its thought can play. [...] An ability to conceptualize the world must include the ability to conceptualize the thinker's own place in the world; and to find the latter ability intelligible, we need to make room not only for conceptual states that aim to represent how the world anyway is, but also for conceptual states that issue in interventions directed towards making the world conform to their content. A possessor of *logos* cannot be just a knower, but must be an agent too; and we cannot make sense of *logos* as manifesting itself in agency without seeing it as selecting between options [...]. This is to represent freedom of action as inextricably connected with a freedom that is essential to conceptual thought. [31]

Hence, freedom in thought and action are linked to one another, and freedom is self-determination: a being is a person and thinks and acts if and only if she positions herself in relation to what is given to her mind in the guise of sensory impressions, desires and needs, and makes up her mind as to what to think and to do.

The same point is brought out by Wilfrid Sellars when he denounces what he takes to be the "Myth of the Given": [32] this is the idea that something that is simply given to the mind has, as such, the epistemic status of being in a position to justify beliefs and actions. Thus, according to Sellars, sense impressions, for instance, construed as the effects of interactions of a person with her environment, cannot, qua being the result of physical *causal* processes, *justify* anything. By the same to-

[31] John McDowell, "Two Sorts of Naturalism", in: Rosalind Hursthouse, Gavin Lawrence, and Warren Quinn (eds), **Virtues and Reasons: Philippa Foot and Moral Theory**, Oxford University Press, Oxford 1995, p. 152 [149–179].

[32] See Wilfrid Sellars, "Empiricism and the Philosophy of Mind", in: Herbert Feigl and Michael Scriven (eds.), **The Foundations of Science and the Concepts of Psychology and Psychoanalysis**, University of Minnesota Press, Minneapolis 1956, pp. 253–305 [253–329].

ken, supposedly innate ideas cannot as such justify anything. The reason is that with respect to whatever is given to her mind, a person has to take the attitude of endorsing what is given as a reliable source of knowledge and guide for actions; only thereby does she confer upon it an epistemic status. Hence, in deliberating about what is given to her mind, the person must herself decide which beliefs she *should* adopt and which actions she *should* take. This conclusion is also strengthened by what Descartes says in the third of his **Meditationes de prima philosophia** about the idea of God: the fact that this idea is given to him does not imply that he *should* believe that there is a God. Only *his* deliberation about this idea, *his* examination of it leads to that conclusion.

This is a transcendental argument: the performance of denying the freedom involved in thought and action would itself be an instance of that freedom by forming a thought, albeit a contradictory one. Functionalism about the mind therefore always comes too late: it can offer a functionalist treatment of the thoughts and actions manifested by a person or group of persons, but it fails to capture the freedom involved in forming a thought or an intention to act. Thus, for instance, if the functionalist claims that everything is realized by matter in motion, and hence identical with a configuration of matter in motion, such that it can be captured by the method of inquiry of natural science (scientism), she commits a performative contradiction: to claim that the matter in motion in the world imposes on us the theory that everything is matter in motion, because the theory itself is nothing but a configuration of matter in motion in the sense that it is nothing beyond the beliefs that persons have, where these are realized by or identical with certain particle configurations in their brains, is a performative contradiction, because any such claim is only itself conceived by exercising the freedom involved in forming thoughts on the basis of whatever is given to one's mind. Taking the content of this claim to be imposed on us by matter in motion in the world would be an instance of the "Myth of the Given". It misses the point of what it is to think and act.

Rejecting the "Myth of the Given" thus leads to a transcendental argument in favour of treating persons as ontologically primitive, on a par with matter in motion: persons must take decisions, and thus answer the question of what they should do, including which beliefs and theories they should accept. This is what is established by the Cartesian argument that one cannot doubt that one thinks. Consequently, normativity is presupposed by the very formulating of what may be

considered the scientific view of the world. This view depends on thought for its existence as a *view*. Formulating and endorsing this view is a choice that persons make and that can only be justified within the sphere of normative attitudes of giving and asking for reasons. The referents of the theory — whatever the theory poses as existing in the world — cannot impose acceptance of the theory on persons, or justify this. In that sense — as beings that formulate and justify theories — persons are indispensable, and so primitive: whatever the theory, persons must conceive, endorse and justify it. Consequently, insofar as they formulate scientific theories and the scientific view of the world as a whole, persons cannot be located or placed within what science poses as existing.

Persons, qua thinking and acting beings (*res cogitans*), can be conceived by analogy with matter in motion (*res extensa*) in the following sense: as matter in motion is individuated by distance relations that make it such that the entities that stand in these relations are *matter* points, so persons qua thinking and acting beings can be taken to be individuated by normative relations of justification that mean that the entities that stand in these relations are *mind* points. In that way, one can vindicate the Cartesian dualism of *res extensa* and *res cogitans* without being committed to two kinds of substances that can exist independently of one another. As all there is to matter is certain relations and their alteration, i.e. distance relations, so all there is to minds will be certain relations and their changes, i.e. normative relations of justification. [33]

5. Conclusion

Science, broadly conceived as the exercise of reason built on argument and evidence, is a twofold enterprise: there is the science from the point of view of nowhere, i.e. natural science and its method, which is empirical, being concerned with matters of fact and *a posteriori*. And there is the science of human thought and action from the first-person perspective, which operates with a transcendental argument and is normative and *a priori*. Each depends on the other. On the one hand, the very formulation, testing and justifying of scientific theories in the

[33] See Michael Esfeld and Guillaume Köstner, "Normative Relations, Mind Points and Social Ontology", *Synthese* 2022, Vol. 200, No. 6, article number 455, https://doi.org/10.1007/s11229-022-03889-3.

first sense presupposes the freedom in thought and action, and the normative attitude, that are the subject of inquiry of the transcendental, *a priori* argument formulated from the first-person perspective. On the other hand, human thought and action presupposes for its very existence and operation certain natural conditions (organisms with brains) that are the object of enquiry revealed from the third-person perspective, this being the (point of) view from nowhere. How to bring these two stances together without subsuming one into the other is the Cartesian predicament that remains with us today: through its method of objectivity, Cartesian science has made possible enormous technological progress, that has in turn greatly improved humanity's living conditions. Nevertheless, it also leaves us with the issue of how to understand the relationship between ourselves as thinking and acting beings and the world as described by Cartesian science.

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References

Allison Henry and Heath Peter (eds.), **Theoretical Philosophy After 1781**, trans. Gary Hatfield, Michael Friedman, Henry Allison, and Peter Heath, *The Cambridge Edition of The Works of Immanuel Kant*, Vol. 3, Cambridge University Press, Cambridge 2002.

Bell John S., **Speakable and Unspeakable in Quantum Mechanics**, *Collected Papers on Quantum Philosophy*, Cambridge University Press, Cambridge 1987.

Blumenberg Hans, **The Legitimacy of The Modern Age**, trans. Robert M. Wallace, MIT Press, Cambridge – London 1983 (German original: **Die Legitimität der Neuzeit**, Suhrkamp, Frankfurt 1966).

Chalmers David J., **The Conscious Mind: In Search of a Fundamental Theory**, Oxford University Press, Oxford 1996.

Cooper John M. (ed.), **Plato: Complete Works**, Hackett Publishing Co., Indianapolis 1997.

de Caro Mario and Macarthur David (eds.), **Naturalism in Question**, Harvard University Press, Cambridge 2004.

de Muralt André, **L'enjeu de la philosophie médiévale: études thomistes, scotistes, occamiennes et grégoriennes**, Brill, Leiden 1991.

Descartes René, **Discours de la méthode**, Jean Maire, Leyden 1637.

Descartes René, **Meditationes de prima philosophia,** Soly, Paris 1641.

Descartes René, **Œuvres de Descartes. Volume 6. Publié par Charles Adam et Paul Tannery**, Cerf, Paris 1902.

Descartes René, **Principia Philosophiae**, Part Two, Elsevier, Amsterdam 1644.

Esfeld Michael, "Quantum Entanglement and A Metaphysics of Telations", *Studies in History and Philosophy of Modern Physics* 2004, Vol. 35, No. 4, pp. 601–617, https://doi.org/10.1016/j.shpsb.2004.04.008.

Esfeld Michael and Deckert Dirk-André, **A Minimalist Ontology of The Natural World**, Routledge, New York 2017.

Esfeld Michael and Köstner Guillaume, "Normative Relations, Mind Points and Social Ontology", *Synthese* 2022, Vol. 200, No. 6, article number 455, https://doi.org/10.1007/s11229-022-03889-3.

Esfeld Michael and Lam Vincent, "Moderate Structural Realism About Space-Time", *Synthese* 2008, Vol. 160, No. 1, pp. 27–46, https://doi.org/10.1007/s11229-006-9076-2.

Feigl Herbert and Scriven Michael (eds.), **The Foundations of Science and the Concepts of Psychology and Psychoanalysis**, University of Minnesota Press, Minneapolis 1956.

Foster John, **The Case for Idealism**, *International Library of Philosophy*, Routledge, London 1982.

French Steven and Ladyman James, "Remodelling Structural Realism: Quantum Physics and The Metaphysics of Structure", *Synthese* 2003, Vol. 136, No. 1, pp. 31–56; https://doi.org/10.1023/A:1024156116636.

Gerhardt Carl Immanuel (ed.), **Die philosophischen Schriften von G. W. Leibniz**, Band 7, Weidmannsche Verlagsbuchhandlung, Berlin 1890.

Hall Ned, "Humean Reductionism About Laws of Nature". Unpublished manuscript, 2009, pp. 1–55, https://tiny.pl/wc7f9 [14.11.2022].

Hursthouse Rosalind, Lawrence Gavin, and Quinn Warren (eds), **Virtues and Reasons: Philippa Foot and Moral Theory**, Oxford University Press, Oxford 1995, pp. 149–179.

Jackson Frank, **From Metaphysics to Ethics: A Defence of Conceptual Analysis**, Oxford University Press, Oxford 1998.

Kant Immanuel, "Prolegomena to Any Future Metaphysics that will be Able to Come Forward as Science", in: Allison and Heath (eds.), **Theoretical Philosophy…**, pp. 29–170.

Ladyman James, "What is Structural Realism?", *Studies in History and Philosophy of Modern Science* 1998, Vol. 29, No. 3, pp. 409–424, https://doi.org/10.1016/S0039-3681(98)80129-5.

Lazarovici Dustin and Reichert Paula, "Typicality, Irreversibility and The Status of Macroscopic Laws", *Erkenntnis* 2015, Vol. 80, No. 4, pp. 689–716, https://doi.org/10.1007/s10670-014-9668-z.

Leibniz' third letter to Clarke, in : Gerhardt (ed.), **Die philosophischen Schriften…**, pp. 363–364.

Lewis David, "How to Define Theoretical Terms", *Journal of Philosophy* 1970, Vol. 67, No. 13, pp. 427–446, https://doi.org/10.2307/2023861.

Lewis David, "Psychophysical and Theoretical Identifications", *Australasian Journal of Philosophy* 1972, Vol. 50, No. 3, pp. 249–258, https://doi.org/10.1080/00048407212341301.

Lewis David, **On the Plurality of Worlds**, Blackwell, Oxford 1986.

Loewer Barry and Schaffer Jonathan (eds.), **A Companion to David Lewis**, *Blackwell Companions to Philosophy*, John Wiley & Sons, Inc., Malden — Oxford — West Sussex 2015.

Mach Ernst, **The Science of Mechanics: A Critical and Historical Account of its Development**, trans. Thomas J. McCormack, Fourth Edition, Open Court, Chicago 1919 (German original: **Die Mechanik in Ihrer Entwickelung Historisch-Kritisch Dargestellt**, Brockhaus, Leipzig 1897).

Maudlin Tim, **Philosophy of Physics: Quantum Theory**, Princeton University Press, Princeton 2019.

McDowell John, "Two Sorts of Naturalism", in: Hursthouse, Lawrence, and Quinn (eds), **Virtues and Reasons…**, pp. 149–179.

Newton Isaac, **Philosophiae Naturalis Principia Mathematica**, Royal Society, London 1687.

Plato, **Parmenides**, trans. Mary Louise Gill and Paul Ryan, in: Cooper (ed.), **Plato…**, pp. 359–397.

Popper Karl R., **The Poverty of Historicism**, Routledge, London 1957.

Price Huw, "Naturalism Without Representationalism", in: de Caro and Macarthur (eds.), **Naturalism in Question…**, pp. 71–88.

Sellars Wilfrid, "Empiricism and the Philosophy of Mind", in: Feigl and Scriven (eds.), **The Foundations of Science…**, pp. 253–329.

von Hayek Friedrich August, **The Counter-Revolution of Science: Studies on The Abuse of Reason**, Free Press, Glencoe 1952.

Watson James D. and Crick Francis H.C., "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid", *Nature* 1953, Vol. 171, No. 4356, pp. 737–738, https://doi.org/10.1038/171737a0.