Chapter 3
Old and New Mechanistic Ontologies

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Abstract The concept of mechanistic philosophy dates back to the beginning of the early modern period. Among the commonalities that some of the conceptions of the main contemporary representatives share with those of the leading early modern exponents is their ontological classification: as regards their basic concepts, both contemporary and early modern versions of mechanism can be divided into monist and dualist types. Christiaan Huygens' early modern mechanistic explanation of non-material forces and Stuart S. Glennan's contemporary conception of mechanism will serve as examples of monism. As examples of dualism, I will discuss Isaac Newton's early modern mechanistic philosophy of nature and the contemporary conception of mechanism proposed by Peter Machamer, Lindley Darden, and Carl F. Craver. With the ontological commonalities are associated further characteristic features of the respective types that concern, among other things, the respective understandings of fundamental theories and evaluations of scientific practice. The ontological continuity of the types does not play any role in contemporary discussions of the history of mechanistic philosophy. On my assessment the distinction between monism and dualism remains an unsolved problem and its persistence is an indication that this distinction is a fundamental one.

3.1 Introduction

It is a matter of controversy whether one can formulate a uniform concept of mechanistic philosophy for a certain period and whether it can be traced back to the early modern era. While its leading contemporary exponents portray themselves as a

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joint movement,[1] early modern mechanism is a post facto reconstruction that can be undertaken in a variety of ways. In the context of early modern philosophy, mechanism can mean the orientation to physical mechanics, the use of the machine metaphor to explain natural phenomena, or the mathematization of scientific knowledge—to name only a few, not always easily distinguishable, examples.[2] Early modern mechanistic thought dealt primarily with inanimate nature, though it also extended to the phenomena of life. For the biological sciences, Daniel J. Nicholson claims that no continuity exists between the important early modern meanings of mechanism and the contemporary meanings, which deal mainly with living phenomena.[3] However, the leading contemporary exponents by no means deny that there is some common ground with early modern mechanism.[4]

My comparison between the historically widely separated ontological meanings is based on points of contact between a present-day concept of mechanism and one applied to early modern philosophy. For the present-day concept of mechanism. I refer to texts by authors who are generally recognized as its leading exponents. Their conceptions are commonly divided up into the three groups comprising (1) Peter Machamer, Lindley Darden, and Carl F. Craver (hereafter abbreviated as "MDC"), (2) Stuart Glennan, and (3) William Bechtel and Adele Abrahmson. The epistemic and methodological commonalities that exist between them have been repeatedly highlighted.[5] For early modern mechanism, I propose a broad and a narrow concept that to a sufficient extent include the conceptions that were influential at that time while exhibiting points of contact with the contemporary concept. Mechanism, broadly conceived, treats matter in motion as the first and only cause of all natural phenomena and, narrowly conceived, it postulates that the forms of motion are determined by the principles of a specific discipline, namely, mechanics. In what follows I will confine myself to the narrow concept.

Assuming the concepts of early modern and contemporary mechanism, we can draw up a rough list of their commonalities and differences. As commonalities, I would cite the search for causal explanations of phenomena that are not based on supernatural forces, the rejection of a categorical distinction between natural and technical phenomena, the quest for a unified scientific method, the close connection to scientific practice, and, finally, the correspondence that concerns me in the present text—the possibility of classifying some conceptions under the same ontologi-

[1] Levy and Bechtel 2016 use the term "mechanism 1.0" to refer to some of the commonalities. Illari and Williamson 2012, Craver and Tabery 2015, Glennan 2016, and Glennan and Illari 2017 suggest minimal definitions of mechanism that resemble each other. Andersen 2014 argues against a unified concept of contemporary mechanism.

[2] See Schiemann 1997 for the orientation to physical mechanics, Mumford 1981 for the machine metaphor, Dijksterhuis 1956 for the mathematization of scientific knowledge.

[3] Nicholson 2012, 154.

[4] For example, Glennan 1992, 12ff., Craver and Darden 2005, and Bechtel 2006, 20ff..

[5] See n. 1.

cal types. Before examining the ontological commonality more closely, I would like to mention as differences those aspects which are characteristic of the early modern, but not of contemporary, mechanism: the limitation of the *explanans* to matter in motion and the associated effort to reduce all phenomena to this type of change. Contemporary mechanism, by contrast, recognizes both reductionist and non-reductionist explanations without being restricted to matter in motion.[6]

The ontological types of early modern mechanistic philosophy are a function of the different ways in which they relate the concepts of matter and force. Matter is conceived as the substance in which location-changing movement takes place. It can be divided either discretely or continuously into segments, but it must be inherently unchangeable and be differentiated at most in the purely quantitative attributes of its particular form— i.e. size and shape. Forces may be responsible for cohesion among the various material particles, for their gravity, and for the movements, or kinds of movements, they make. "Monistic" views either reject an independent concept of force (e.g., Robert Boyle and Huygens) or, conversely, explain all properties of matter as effects of forces (e.g., Gottfried Wilhelm Leibniz and Immanuel Kant). An intermediate position between these two extremes is taken by the "dualistic" mechanism that conceives of matter and force as irreducible basic concepts (e.g., Newton and Roger Boscovich).[7]

A similar classification can now be made for two of the three groups of the main present-day proponents of mechanism. It refers to the relationship between the concepts of entity and activity. Both terms are defined contextually, and they are not used in entirely uniform ways. The term entity is sometimes used synonymously with that of part, the term activity sometimes synonymously with that of interaction between parts.[8] MDC describe the ontology of their conception explicitly as a dualist one and classify Glennan (1996) under substantivalism.[9] I would like to show in the following that this self-characterization is correct and that Glennan's monism concerning entities can be interpreted as a version of substantivalism. Furthermore, it must also be demonstrated that the conceptual pairs "entity/activity" and "matter/force" are at least structurally related. For this purpose, I will refer to the context of physical phenomena.

I will begin with a discussion of examples of the ontological difference in a narrow early modern version of mechanism (Sect. 3.2), then analyze the two ontologically related conceptions of contemporary mechanism (Sect. 3.3), and, in conclusion, highlight some aspects of the comparison between the early modern and contemporary conceptions of mechanism presented (Sect. 3.4).

[6] Williamson 2011.

[7] Schiemann 2009, 15ff. and 33ff.

[8] For example, Illari and Williamson 2012, and Glennan 2016.

[9] Machamer et al. 2000 (hereafter cited as "MDC 2000"), 4f.

3.2 Early Modern Mechanism

3.2.1 Monism in Christiaan Huygens

Under "materialistic" monism I understand the version of mechanism that rejects non-material forces as explanatory entities and recognizes pure contact between material bodies as the only possible form of natural interaction. The phenomena are explained in terms of pressure and impact processes between elementary bodies.[10] The first historically influential articulation of this mechanism was Robert Boyle's conception of nature, though this can be described as mechanistic only in a broad sense. In the work of Christiaan Huygens, the second prominent representative of materialist monism, physical mechanics becomes the structuralizing principle.

In his conception of nature, Huygens builds directly on Boyle and he places the explanation of the phenomena of light and the weight of bodies at the center of his mechanism.[11] Specifically for the purpose of deducing gravity from mechanical centripetal forces, he postulates a fine-grained and weightless ethereal substance that rotates in a spherical vortex motion around the earth, pushing bodies toward the center of the earth.[12] According to Huygens, the space between the ether particles is empty, so that he can attribute the free mobility required for the calculations of mechanics to these particles.[13]

Huygens' atomism ascribes hardness as a property to both the ether particles and the non-ethereal parts of which all bodies are composed.[14] Because matter is supposed to be the sole first cause of all phenomena, so that it cannot have different degrees of hardness, he has to posit the resistance caused by hardness as absolute.[15] Huygens ignores the dictate of intuitive representations that dominates early modern scientific discourse and postulates that elementary collisions are elastic despite the absolute hardness of the collision partners:

> Whatever may be the cause of hard bodies rebounding from mutual contact when they collide with one another, let us suppose that when two bodies, equal to each other and having equal speed, directly collide with one another, each rebounds with the same speed which it had before the collision (Huygens 1977, 574).

On this assumption, he provides a correct formulation of the laws governing elastic collisions, but not a correct explanation of gravity.[16]

Huygens' success in deriving the laws of collisions comes at the cost of the non-intuitiveness of his concept of matter and contrasts with his failure to provide an

[10] See the definitions of Kirchner 1833, 212f., and Brugger (Ed.) 1950, 213.

[11] On Huygens' mechanistic philosophy of nature, see Lasswitz 1890, Vol. 2, 341ff., Westman 1980, Snelders 1980 and Gabbey 1980. On the following, see Schiemann 1997, 95ff.

[12] Huygens 1896, 5ff.

[13] Loc. cit., 31f.

[14] Ibid. See Lasswitz 1890, Vol. 2, 360ff.

[15] Letter from Huygens to Leibniz of 11.7.1692, in Leibniz 1849ff., Vol. 2, 139.

[16] See Dühring 1873, 165ff. and Dugas 1957, 176ff.

explanation of gravity (a problem that remains unsolved to the present day). In his discussion of early modern corpuscularism, under which he classifies Huygens, Glennan interprets this failure as an early indication that gravity cannot be explained in mechanistic terms in principle.[17] In the case of fundamental forces such as gravity, according to Glennan, the causal understanding of the world as such reaches its limits with (not only early modern) mechanistic explanations formulated in causal terms.[18] I will return to the importance of the existence of a fundamental level for Glennan's and MDC's conceptions of mechanism below.

At this point, it should be noted that Glennan (in contrast to MDC) understands his conception as the result of a critical confrontation with the early modern variants of mechanism.[19] Huygens' mechanism also shows, according to Glennan, that the explanation of the phenomena must not be confined to mechanical pressure and impact processes.[20] He regards the liberation from this strict requirement as the decisive precondition for the triumph of Newton's mechanistic explanation of the movements of bodies in space.

3.2.2 Isaac Newton's Dualism

Fundamental to the early modern understanding of mechanical forces is the distinction between the uniform inertial motion of material bodies free of forces, on the one hand, and changes in this motion caused exclusively by forces, on the other.[21] If we assume that matter is initially in motion, then any subsequent change in motion of material bodies requires a measurable mechanical force, which, in dualistic and narrowly conceived mechanism, has the status of the only permissible cause for changes in nature—apart from the effects that can be attributed to the shapes assumed by atoms (adhering, interlocking, etc.). Forces can exercise effects without bodies having to touch each other because the forces, which in narrow dualist mechanism only act between material bodies, operate even when the material bodies in question are spatially separated. The relevant conception of matter is atomistic and the vacuum or the ether is where forces operate.[22]

[17] Glennan 1992, 13ff. and 138.

[18] Loc. cit., 174f.

[19] Andersen 2014, 281, points to Glennan's greater indebtedness to the history of mechanism in comparison to MDC (and Bechtel).

[20] Glennan 1992, 19ff.

[21] The assumption of inertial motion presupposes the existence of matter independent of forces. However, forces only work between material bodies. In this respect, dualistic mechanism exhibits an affinity with Cartesian metaphysics, in which non-human creatures do not have minds, but the mind occurs in the experienceable world only together with the human body. See n. 50.

[22] On this and the following, see, Thackray 1970, Westfall 1971, Freudenthal 1982 and Schiemann 2009, 35ff.

Newton's narrow mechanism is structured along the lines of his theory of gravitation. Gravity refers to the attractive force postulated by Newton that operates in empty space along the straight line connecting the centers of gravity of two macroscopic bodies with a value proportional to their masses and inversely proportional to the square of the distance between them. Because, according to Newton, nature "will [always] be very conformable to herself and very simple" (Newton 1704, 258) similar forces must also operate between small submicroscopic parts, of which he assumes all material things are composed.[23]

The essential attributes of the smallest parts are exactly the same as those of all things "that we handle" and that can be examined by simple experiments (Newton 1999, 795). For Newton, these are: "extension, hardness, impenetrability, mobility" and, finally, the "force of inertia" (ibid.). In contrast to gravity, whose strength depends on distance, inertia is an invariant attribute.[24] It is a "passive principle" through which "there never could have been any motion in the world" (Newton 1704, 258). For Newton, an "other", "active principle" is realized in the effects of forces (ibid) that, together with the passive principle, collectively constitute a dualism upon which all natural phenomena rest.

Newton was famously reticent when it came to statements about the nature of gravity. He thought, however, that an explanation that goes beyond his mechanical theory was desirable. He himself considered both non-mechanical origins[25] and mechanistic-materialistic causes.[26] Without having found a solution, he made the decisive determination for dualistic mechanism at least in a negative sense. In the "Rules for the Study of Natural Philosophy" that introduce the third book of the *Principia* he writes: "Yet I am by no means affirming that gravity is essential to bodies" (Newton 1999, 796). In this way, matter and force are distinguished from each other as two principles of the mechanistic explanation of nature in a manner characteristic of this tradition. They are juxtaposed as a passive and an active principle and mutually condition each other.[27]

Glennan argues that the ontological difference in Newton's mechanism represents methodological progress. Newton, he argues, recognized that a mechanistic explanation of bodily motion was possible even though the nature of gravity itself remained unexplained.[28] Following Newton, Glennan advocates a hierarchically structured theory of levels: In this case, the lower level is formed by fundamental processes that induce gravitation and that Huygens wanted to understand as a presupposition of natural explanation; the upper level consists of the perceptible and measurable mechanical effects of gravity and movements of bodies. According to

[23] Loc. cit., 261.

[24] Newton 1726, 388.

[25] Loc. cit., 237.

[26] Newton 1704, 385.

[27] On the polarity of the two principles in Newton, see Freudenthal 1982, 40ff. and 265ff.

[28] Glennan 1996, 20f. Similarly, Bechtel 2006, 20ff., describes the history of mechanism from the beginning of the modern era to the present day as a process of progressive detachment from initially restrictive mechanical requirements.

Glennan, we owe Newton the insight that explanations of the phenomena of the upper level are independent from those of phenomena of the lower level. Remarkably, however, Glennan, unlike Newton, rejects an independent concept for the forces or active principles that exert effects in the upper level, as I will explain in the next section.

3.3 Contemporary Mechanism

3.3.1 Monism in Stuart S. Glennan

Glennan's mechanism has been characterized in various places as monism. Thus Ivarola et al. (2013) describe Glennan's position as a "monist position according to which mechanisms are composed of entities interacting in a stable way" (Ivarola et al. 2013, 22).[29] Glennan has maintained the monistic position in essence since his first formulation of mechanism in 1992. Modifications he has made involve changes in the definition of the interactions between the entities to which interactions are attributed as properties.

Entities have an explanatory character. As part of a complex system, they give rise to its properties through their interactions.[30] From the beginning Glennan also uses the expression "part" for the concept of entity.[31] It is conceived in a broad sense in order to be able to satisfy as general a claim to validity as possible:

> Parts may be simple or complex in internal structure, they need not be spatially localizable, and they need not be describable in a purely physical vocabulary. … The parts of mechanisms must have a kind of robustness and reality apart from their place within that mechanism. Care must be taken so that parts are neither merely properties of the system as a whole nor artifacts of the descriptional vocabulary. I shall summarize these restrictions by saying that parts must be objects (Glennan 1996, 53).[32]

Entities encompass far more than just the material bodies that served as *explanans* in early modern mechanism. Depending on the context, they can render an independent concept of force superfluous or also designate objects that correspond to this concept. An independent concept of force is dispensable insofar as forces can be described through changes in the properties of entities. Glennan initially defined

[29] Correspondingly also Gebharter and Kaiser 2014, 63, Kaiser and Krickel 2016, 22, and Kaiser 2017, 116 and 121f. According to Torres 2009, 238, Glennan could also dispense with interactions as a matter of ontology: "Glennan's ontology posits entities as ontologically basic with interactions serving a solely descriptive purpose in mechanism models." However, this seems to contradict Glennan's own account of his position (see quotation to n. 31). An example of Glennan's own monistic definition of mechanism can be found in Glennan 2002, S352: "mechanisms are collections of parts."

[30] See the definitions of mechanism in Glennan 1992, 24, and Glennan 1996, 52.

[31] For example, Glennan 1992, 30: "This description would lead to a decomposition of the system in which the parts were electrons, molecular lattices, or other such entities."

[32] Cf. Glennan 1992, 31f.

changes in properties in terms of the concept of law. Taking the example of Newton's law of gravitation, he shows how force dissolves, as it were, in the law-governed changes in location involved in the movements of parts.[33] Within the framework of Glennan's approach, Newton's dualism in this way becomes a form of monism.[34] However, the broad understanding of the concept of entity can also refer directly to interactions, as Glennan explains using the example of the electromagnetic field, which describes phenomena that satisfy the early modern concept of force.[35]

Glennan subsequently replaced the concept of law with the more general concept of "invariant, change-relating generalizations" that he adopted from Jim Woodward's theory of causation.[36] By including the predicate "change-relating" in the definition of interactions, he reinforces their characterization as properties of entities on which change operates. At the same time, the new definition addresses an objection against using the concept of law also made by MDC (2000), according to which the regularities of mechanisms cannot be described in terms of laws in certain object domains, such as those of molecular biology and of neurobiology.[37] Invariant generalizations can, but need not, be laws. They do not claim the exceptionless validity of laws.[38]

Like the broad concept of entity, the new definition of interactions follows the quest for a validity claim that tries to capture all scientific objects in principle.[39] The universality of Glennan's mechanism also subserves the abovementioned hierarchically structured theory of levels, which takes up the idea, going back to ancient atomism and revived in early modern times, of explaining phenomena (in the upper level) in terms of the mechanisms underlying them (in the lower level). According to Glennan, every mechanism can be the object of a deeper-level explanation until a fundamental level has been reached for which there is no further explanation.[40] As examples of presumably fundamental interactions, Glennan cites physical forces such as gravity or electromagnetic interactions.[41] With early modern materialist monism, which I introduced with reference to Huygens, Glennan shares the reductionist quest for a fundamental explanation. Unlike Huygens, however, Glennan

[33] Glennan 1992, 38f.

[34] In this way, the concept of force is traced back to matter only in a formal sense, however, but is not explained in the sense of early modern materialist monism. Gustav Kirchhoff defended a similar approach in his mechanics (Kirchhoff 1876).

[35] Glennan 1992, 34ff. The forces described by the electromagnetic field were also an object of mechanism in the early modern period. Thus, Johannes Kepler assumed that magnetic forces operate between moving masses, as Newton was aware (Wilson 2002, 204f). Pierre Gassendi tried to explain these forces in mechanistic terms (Fischer 2013).

[36] Glennan 2002, S344ff., Woodward 2000.

[37] MDC 2000, 7.

[38] Glennan 2002, S345.

[39] Since 1992, Glennan defends a claim to validity for his theory of explanation that encompasses scholary knowledge as a whole.

[40] Glennan 1992, 138ff., Glennan 2002, 18. See Torres 2009, 238 and Williamson 2011, 429ff. However, Glennan 2016, 814, concedes that there also cannot be any fundamental level.

[41] Glennan 1992, 138. Cf. n. 17 and Glennan 2002, 18.

affirms the autonomy of the non-fundamental explanations for which Newton's dualistic mechanism provides an example. Glennan can integrate the pair of concepts that occur in dualism into his broad concept of entity.

In recent publications, Glennan understands interactions as a subset of activities, whereby it remains unclear whether he adopts MDC's concept of activity and thus makes a concession to their dualistic mechanism, or whether, on the contrary, he thinks that he can integrate elements of their approach into his monism.[42] On the one hand, this openness may be due to the fact that ontological differences increasingly play only a subordinate role for the application of the models of mechanistic explanation to scientific practice.[43] On the other hand, dualism claims with some justification that it does better justice to the phenomena for practical purposes than monism, as we will see.

3.3.2 Dualism in Peter Machamer, Lindley Darden, and Carl F. Craver (MDC)

MDC (2000) justify their dualism as an attempt to overcome the one-sidedness of monistic approaches, which they identify as substantivalism and process ontology.[44] By subsuming Glennan (1996) under substantivalism, they relate the latter to contemporary mechanism. Substantivalism "confine[s] [its] attention to entities and properties, believing that it is possible to reduce talk of activities to talk of properties and their transitions" (MDC 2000, 4).[45] This characterization is incorrect insofar as Glennan's context-relative concept of entity does not assume the immutability of substances. Nevertheless, it has a certain justification insofar as the concept (following an early modern tradition) also includes a persistent fundamental or substantial level of objects that resists explanation.

Process ontologists "reify activities and attempt to reduce entities to processes" (loc. cit., 5). The first part of this characterization ("reify activities") describes a concept that resembles the early modern monism of force, provided that forces fall under the concept of activity. By demarcating their dualism from two monistic conceptions, MDC cover, at least in a rudimentary way, a spectrum that exhibits a striking resemblance to the three ontological types of early modern mechanism

[42] Glennan 2016, 799, referring to Glennan (forthcoming).

[43] Glennan 2016, 799, does not attach any special importance to the difference between his concept of interaction and the concept of activity that he still criticized in Glennan 2010, 320ff. Having distanced himself in MDC 2000 from Glennan's and Bechtel's concept of interaction, Craver — in Craver and Tabery 2015, stressing the importance of scientific practice for mechanism — declares the differences between the three groups of the main representatives to be bridgeable.

[44] MDC's Mechanism has been characterized in various places as dualism, e.g. Tabery 2004, 2, Torres 2009, 233ff., Illari and Williamson 2013, 69ff., and Kaiser 2017, 116 and 121–124.

[45] According to Glennan 2010, 320f., MDC not only classify his own conception under substantivalism but also that of Bechtel and Richardson 1993.

(see section 1). However, process ontology, of which Rescher's process metaphysics is cited as an example,[46] occupies only a relatively marginal position in contemporary discussions of mechanism.[47]

MDC object that substantivalism does not take sufficient account of the productivity captured by the concept of activity with which changes in properties of entities are effected. [48] Entities do not bring about the changes in their own properties. What in Glennan has the character of a black box[49] is covered by the concept of activity in MDC. They criticize process ontology in more specific terms than substantivalism. Since there are no activities unrelated to entities in the field of neurobiology and molecular biology on which MDC's mechanism concentrates, process ontology, they argue, is not applicable because it denies the necessity of this relation. MDC's concept mechanism assumes that

> Mechanisms are composed of both *entities* (with their properties) and *activities*. Activities are the producers of change. Entities are the things that engage in activities. … Entities and activities are correlatives. They are interdependent. … There are no activities without entities, and entities do not do anything without activities (MDC 2000, 3, 6 and 8).

They juxtapose a passive and an active principle in a way comparable to Newton's early modern dualism. However, the assertion that entity and activity are indissolubly linked ("interdependent") is at odds with the dualist idea that the two principles distinguished are also independent of each other.[50] By denying that activities occur without entities and that entities occur without activities, dualism moves closer to monism.[51]

Notwithstanding the interdependence of entity and activity, the associated concepts remain clearly distinct from each other. The concept of entity is at first circumscribed in a similarly vague way to Glennan's conception as "parts in the mechanism with their various properties" (Craver and Darden 2013, 16), but is then restricted primarily through the definition of the concept of activity. This includes not only objects of explanation of different disciplines but also their historical transformations. To the concept of activity belong, for example, geometric-mechanical activities, which describe both the interactions between the corpuscles of early modern materialistic mechanism and the "fitting of a neurotransmitter and a post-synaptic

[46] Rescher 1996.

[47] See Williamson 2011, Illari and Williamson 2013 and Andersen 2014. Levy and Bechtel 2016, 14, nevertheless identify the orientation to process ontology as an option for the future development of mechanism ("mechanism 2.0").

[48] MDC 2000, 5.

[49] Tabery 2004, 10f.

[50] In modern dualism, this independence is not entirely symmetrical. See n. 21. Descartes' dualism postulates bodies without mind (non-human organisms) and mind without a body, i.e. human souls, but in human beings minds do not occur without bodies. For contemporay mechanism, Illari and Williamson 2012, 130f., show that activities are conceivable without entities and entities without activities.

[51] Glennan 2010, 321 points out this proximity when he treats the concepts of interaction and activity as interchangeable. "Where MDC speak of entities and activities, … Glennan speak[s] of parts and interactions" (ibid.).

receptor" (MDC 2000, 14). But gravity and other physical interactions (e.g., electrostatic attraction and repulsion, magnetism) are also examples of activities[52] that Glennan ascribes at the same time to the entities or their interactions.

Like Glennan, MDC also assume that mechanistic explanation exhibits a hierarchical level structure.[53] Unlike him, however, they do not assume that there is a fundamental level underlying all mechanistic explanations. The range of mechanistic explanation is determined in pragmatic terms and comes to an end where the next-lower level is irrelevant to the epistemological interest.[54] MDC radicalize Newton's insight of the independence of higher-level explanations.

In addition to its conceptual innovation over other approaches (specifically, substantivalism and process ontology), MDC cite "descriptive adequacy" as a further justification for dualism (loc. cit., 8ff.).[55] In this way they emphasize the special importance that their approach attaches to the relation to scientific practice. Accordingly, they demonstrate the applicability of dualism using textbook examples of neurobiologists.[56]

3.4 Concluding Comparative Remarks

The early modern pair of concepts "matter" and "force" is structurally related as regards the contrast it draws to the contemporary conceptual pair "entity" and "activity." There are also overlaps at the level of content, in that the concept of matter is contained in that of entity and the concept of force is subsumed in part into the concept of (monistic) entity, in part into the (dualistic) concept of activity.

Through their reference to the context of mechanics, the early modern basic concepts were conceived much more narrowly than the basic concepts of contemporary mechanism. Contemporary mechanism has come closer to fulfilling the shared quest of the historically widely separated conceptions to achieve a uniform method of natural scientific knowledge simply because its basic concepts are wider in scope. However, this is also one of the reasons why the contrast between monism and dualism has become weaker. Unlike the materialistic monism of the early modern era, contemporary monism is no longer forced to explain interactions between the entities. There was a clearer separation between the concept of matter of the early modern materialistic monists and that of force than in contemporary monism, as far as this was dealt with here. The reduction task facing the early modern monists was correspondingly demanding—or rather, unrealizable. Glennan, by contrast, can integrate interactions into his broad concept of entity.

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[52] Craver 2007, 64.

[53] MDC 2000, 4, 7, and 13f.

[54] Loc. cit., 13.

[55] As motivation for the dualistic approach to activities they specify ontological, descriptive, and epistemic adequacy (loc. cit., 4)—the last of which I have not discussed.

[56] According to Andersen 2014, 275, MDC belong to the group of "mechanisms as integral to scientific practice," Glennan, by contrast, to the group of "mechanisms as an ontology of the world."

Ontological differences played a much greater role in the early modern discourse about science than in contemporary philosophy of science.[57] This has also contributed to leveling the difference between contemporary monistic and dualistic approaches. All the more remarkable is the persistence of ontological questions, albeit in an attenuated form.

Present-day monism is associated with a form of reductionism that—similar to early modern monism—aims at a fundamental level. The characterization of this level makes use of a non-intuitive terminology. In Huygens it took the form of the mathematical and physical laws of the idealized elastic collision; Glennan accepts that the causal understanding of the world, which is otherwise indispensable, may fail at the fundamental level, assuming it exists.

Contemporary mechanism as a whole—as Glennan correctly emphasizes—is indebted to early modern dualism for the insight that successful explanations are possible even if the underlying processes are not yet understood.[58] As in the early modern period, contemporary dualistic mechanism enjoys the advantage over its monistic counterpart that its terminology is more closely related to scientific practice. The phenomena of the world seem to have a widespread dualistic character.[59] Dualism can provide a basis for good explanations even without having been explained itself. But monism, on the other hand, has the advantage that it remains an option for explaining dualism.

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[57] According to Cassirer, what sets early modern mechanism apart is the "logical primacy" of the traditional conception of substance (Cassirer 1923, 8). Today, by contrast, the ontological perspective is just one aspect among others, see n. 42 and 54 and Glennan 2016, 796. At the same time there is an ontological continuity of mechanistic explanations from early modern science to current scientific practice, see Falkenburg in Chapter I.4 of this volume.

[58] This can be interpreted as a renunciation of the ontological completeness of explanations. From an epistemic perspective, mechanism during the nineteenth century in addition relinquished the claim to absolute truth when mechanistic explanations are posited as having only hypothetical validity. See Schiemann 2009.

[59] This is also suggested by the physical theories of the very small, which (in the standard model) divide all elementary particles into the two classes of material particles (Fermions) and interaction particles (Bosons). For an introduction, see Carroll 2013 and Hauschild 2016.

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