EMERGING FROM A FRACTURED WORLD:

AN INTERDISCIPLINARY DIALOGUE BETWEEN MECHANISTIC PHILOSOPHY, THE BOHMIAN CAUSAL/ONTOLOGICAL INTERPRETATION OF QUANTUM PHYSICS, EMERGENCE, AND ARISTOTELIAN-THOMISTIC PHILOSOPHY

by

ZIHAO (MARCUS) WANG

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Table of Content

Section I. Introduction.[1]

In his lecture entitled *Unfolding Meaning*, David Bohm, considered by some to be one of the most significant as well as under-appreciated theoretical physicists of the twentieth century,[2] argues that our contemporary society's increasing disregard for the human person and humanities studies is, to a great extent, a result of the currently dominant worldview[3] we inherited from early modernity: mechanical atomism, which sees the physical universe as a vast space filled with material bodies ultimately reducible to their microphysical parts that interact blindly with each other through mechanical forces and laws.[4] This mechanical worldview, which, as the historian of science and environmental philosopher Carolyn Merchant points out, is "now taught in most Western schools [and is] accepted without question as our everyday, common sense reality,"[5] has far reaching implications for humanity's self-understanding:

> The ultimate implications of this [mechanical] view of universal order are, of course, that man is basically insignificant. What he does has meaning only in so far as he can give it meaning in his own eyes, while the universe as a whole is basically indifferent to his aspirations, goals, moral and aesthetic values, and, indeed, to his ultimate fate.[6]

As such, we inherited a fractured world from the scientific revolution of the sixteenth and seventeenth century that sees the universe as "a system of dead, inert particles moved by

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[1] I would like to express my deep gratitude to Dr. Christopher S. Morrissey (Trinity Western University, faculty of philosophy) who, as a dear mentor and friend, has en-kindled my passion for philosophy and introduced me to the study of Aristotelian-Thomism, the thoughts of David Bohm, and so many other significant subjects. This project would not have been possible without his constant support and encouragement.

[2] F. David Peat, *Infinite Potential: The Life and Times of David Bohm* (New York: Basic Books, 1997).

[3] David Bohm, *Unfolding Meaning: A Weekend of Dialogue with David Bohm* (Abingdon-on-Thames: Routledge, 1987), 2.

[4] Bohm, *Unfolding Meaning*, 1-2. To be sure, Bohm is by no means the only thinker to make this line of argument against mechanism; however, the fact that Bohm retrieves and utilizes the Aristotelian formal cause to argue for irreducible wholeness in the context of quantum physics makes Bohm unique amongst modern physicists. See **sections IV-VI** of this thesis below.

[5] Carolyn Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution* (New York: Harper Collins, 1980), 193.

[6] Bohm, *Unfolding Meaning*, 1-2.

external...forces"[7] in which all things can be 'broken apart.' Even seemingly non-mechanical phenomena, such as organisms like plants, animals or human beings, are really just a "convenient way of talking about a lot of molecules"[8] to which the organisms are ultimately reducible. Hence, whilst modern science combined with a mechanistic worldview has given humanity incredible technological progress and ability to predict, control, and manipulate nature (which has also subsequently "contributed to the most pressing ecological and social problems of our day"[9]), the mechanical worldview has also left us in a vacuum without inherent meaning and purposefulness in the world apart from the subjective individual or collective mental constructions of the human race.

Despite the dominance of mechanical atomism over Western intelligentsia since early modernity, the continued advancement of science has brought about new discoveries and realizations that prove challenging to the credibility of this worldview. For example, Bohm argues that the quantum revolution in physics brings potentially revolutionary ontological implications since it reveals "quantum wholeness"[10] that "makes the quantum theory go beyond mechanism of any kind"[11] because quantum wholeness is a state of quantum physical systems that can "actually organize the parts."[12] Significantly, Bohm highlights that quantum wholeness is in fact reminiscent of the classical Aristotelian-Thomistic (A-T) notions of formal and final causations,[13] which mechanical atomism rejects in favour of material and efficient causations.

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[7] Merchant, *The Death of Nature*, 193.

[8] Bohm, *Unfolding Meaning*, 3.

[9] Carolyn Merchant, "The Scientific Revolution and the Death of Nature," *Isis* 97, no. 3 (2006): 517.

[10] David Bohm and Basil J. Hiley, *The Undivided Universe: An Ontological Interpretation of Quantum Theory* (Abingdon-on-Thames: Routledge, 1993), 59.

[11] Bohm and Hiley, *The Undivided Universe*, 58.

[12] Bohm, *Unfolding Meaning*, 7. See also Robert C. Koons, "Thermal Substances: a Neo-Aristotelian Ontology of the Quantum World," *Synthese* 198, no.11 (2021): (5) 2751-2772. https://link.springer.com/article/10.1007/s11229-019-02318-2

[13] David Bohm, *Wholeness and the Implicate Order* (Abingdon-on-Thames: Routledge, 2002), 17.

Quantum wholeness thus "contradicts" and "overturn[s] mechanism"[14] because mechanical atomism entails that the whole is always nothing but, and is ultimately reducible to, the parts. However, this significant paradigm-changing feature of quantum physics that was understood by the founders of quantum mechanics, including Schrödinger, Dirac, and Pauli,[15] has mostly "faded out"[16] of mainstream academic discussion. Bohm argues that this lack of attention paid to the ontological significance of quantum theory is caused by Western academia's over-emphasis on "calculation," and "experimental results," at the expense of the philosophical implications of quantum physics, resulting in Bohm's observation that "I don't think the majority of physicists [at least in Bohm's time] realize how radical the implications of quantum mechanics are."[17]

Fortunately, a renewed interest in the broader metaphysical implications of the advancing discovery of science has been slowly but surely manifesting itself contemporaneously in the form of **emergentism**[18] within the fields of philosophy of science and metaphysics. Emergentism claims that there exist many "[emergent] phenomena – studied by... natural and human sciences – where new processes, interactions, entities, and properties are claimed to be observed, characteristic for higher levels of complexity of matter and irreducible to their lower-level constituents."[19] As such, emergentism goes back at least to ancient Greek philosophers such as Aristotle and mediaeval Scholastic philosophers like Thomas Aquinas, and it has been further developed by early modern and contemporary thinkers such as John Stuart Mill, George Lewes,

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[14] Bohm, *Unfolding Meaning*, 6-7.
[15] Bohm, *Unfolding Meaning*, 7.
[16] Bohm, *Unfolding Meaning*, 7.
[17] This is a significant testimony to the unique ontological reflectivity of the disciplines of humanities, especially philosophy in the broadest sense of metaphysics, which the mere popular 'shut up and just calculate' approach to knowledge eludes.
[18] Mariusz Tabaczek, *Divine Action and Emergence: An Alternative to Panentheism* (Indiana: University of Notre Dame Press, 2021).
[19] Mariusz Tabaczek, "Emergence," In The Palgrave Encyclopedia of the Possible, 2020, Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-98390-5_149-1

Karl Popper, Jaegwon Kim,[20] David Oderberg,[21] Paul Humphreys,[22] Terrence Deacon,[23] Michael Dodds,[24] Eleonore Stump[25], and Mariusz Tabaczek,[26] amongst others. The significance of emergentism as a position in the philosophy of science and metaphysics is that it claims, contrary to mechanical atomism, that there exist realities with distinct intelligibility, meaning, wholeness, purposefulness, causal powers, etc., that cannot be reduced to their microphysical constituents. Prominent examples of emergence include physical phenomena like quantum entanglement, certain chemical and bio-chemical properties such as chemical bonds, the wetness of water[27], and higher level phenomena like animal and human agency and consciousness.[28] As such, emergentism presents a fundamental challenge to the mechanical-atomist worldview by highlighting that a reductionistic-mechanistic philosophy is incapable of giving physical reality an exhaustive account. Therefore, emergentism provides reasons for a critical re-examination of the mechanistic worldview in light of the non-mechanistic import of recent developments in quantum theory that reveal irreducibly emergent and holistic realities.[29]

One contemporary manifestation of this recent metaphysical reflective consciousness is the neo-Aristotelian revival[30] within analytic philosophy championed by notable thinkers such as E.H.Madden, George Molnar, Nancy Cartwright, Rom Harré, Brian Ellis, Alexander Bird,

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[20] Tabaczek, *Divine Action and Emergence*, 27.

[21] David S Oderberg, *Real Essentialism* (New York: Routledge, 2007).

[22] Paul Humphreys, *Emergence: A Philosophical Account* (Oxford: Oxford University Press, 2016).

[23] Terrence W. Deacon, *Incomplete Nature: How Mind Emerged From Matter* (New York: WW Norton & Company, 2011).

[24] Michael J. Dodds, *Unlocking Divine Action* (Washington: CUA Press, 2012).

[25] Eleonore Stump, "Emergence, Causal Powers, and Aristotelianism In Metaphysics," in *Powers and Capacities in Philosophy*, ed. John Greco, Ruth Groff (New York: Routledge, 2013),48-68.

[26] Mariusz Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science* (Indiana: University of Notre Dame Press, 2019). Tabaczek, *Divine Action and Emergence*.

[27] Arnold E. Sikkema, "A Physicist's Reformed Critique of Nonreductive Physicalism and Emergence," *Pro Rege* 33, no. 4 (2005): 20-32.

[28] Tabaczek, *Divine Action and Emergence*, 17. See also Humphreys, *Emergence*, 45-49.

[29] Tabaczek, "Emergence," 2019.

[30] William M.R. Simpson, "From Quantum Physics to Classical Metaphysics," in Neo-Aristotelian Metaphysics and the Theology of Nature, ed. William M.R. Simpson, Robert C. Koons, and James Orr (New York: Taylor & Francis, 2022), 24.

Edward Feser, Eleonore Stump, and Robert.C Koons, amongst others. In fact, in the wake of quantum wholeness and emergentism, growing numbers of thinkers have turned away from mechanism to (amongst other positions) neo-Aristotelian-Thomism (A-T) for an alternative metaphysical worldview. Bohm himself, for example, argues that Aristotle's "formative and final cause"[31] are again required by science to account for wholeness in nature. Claus Emmeche, Simo Køppe, Frederick Stjernfelt, Stump, Koons, William Simpson, Feser, and Mariusz Tabaczek, etc., too argue that emergent wholeness in nature, with downward causal power on constituents, can be robustly formulated via Aristotle's notions of formal and final causalities[32] that affirm inherent unity and purposefulness in nature beyond what mechanistic-reductionism can recognize. An emergentist informed neo-Aristotelian-Thomistic metaphysics further entails that since the great variety of things in the universe are not monistically reducible to the microphysical level due to their emergent formal causes or natures, they can be understood as existing on multiple levels or scales, including (but not limited to) "the physical, the biological, the psychic and the social."[33] As such, the entities proper to each existential scale ought to be studied and understood on their own scales via a method of study proper to them, such as the physical sciences, biological sciences, as well as the humanities, and the psychological and social sciences. After all, "All men naturally desire to know,"[34] and the richness of nature thus calls for a multifaceted approach to knowledge that enables one to comprehend and behold being in its ontological abundance,[35] rather than restricting our understanding of it to the microphysical scale

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[31] Bohm, *Wholeness and the Implicate Order*, 18.

[32] Claus Emmeche, Simo Køppe, and Frederik Stjernfelt, "Levels, Emergence, and Three Versions of Downward Causation," in *Downward Causation: Minds, Bodies and Matter*, ed. Peter Bøgh Andersen (Aarhus: Aarhus University Press, 2000), 17.

[33] Emmeche, Køppe, and Stjernfelt, "Levels, Emergence," 15.

[34] Thomas Aquinas, *Commentary on the Metaphysics of Aristotle, 2 vols*, trans. John P. Rowan (Chicago: Henry Regnery Co, 1961), Aristotle's text, Chapter 1, 980a 21.

[35] Which, according to Benedict M. Ashley, is a feature characteristic of the classical Aristotelian approach to the unification of knowledge by a coordination of autonomous sciences. See Benedict M. Ashley, *The Way*

for the sole purpose of technological mastery, a symptom characteristic of a forgetfulness of being.[36]

Section I.1. Thesis Statement: As such, following the call of David Bohm to a contemporary philosophical reflection upon our broader metaphysical worldview in light of quantum wholeness and the growing awareness of emergentism in contemporary science, this thesis argues, **firstly**, that the currently dominant modern mechanical-atomist philosophy is the result of an over-extrapolation[37] of classical physics that is becoming increasingly unfeasible in light of the quantum revolution and emergentism. **Secondly**, a neo-Aristotelian-Thomistic philosophy, with its distinct notions of causal power and formal causation, etc., can both account for the practical utility of mechanistic philosophy as well as supply a solid ontological basis for a robust account of emergent wholeness that can help us to understand the cosmos more adequately as it is increasingly being investigated and understood by science in a holistic and non-reductionistic fashion. **Thirdly**, the Bohmian causal/ontological interpretation of physics provides concrete evidence for the claims of emergentism that there exist irreducibly emergent phenomena in nature. As such, the Bohmian interpretation points to and can be connected to both emergentism and the neo-Aristotelian-Thomistic metaphysics in a mutually enriching and fulfilling fashion.

Road Map: This thesis will then proceed by a discussion of the history, nature, and key characteristics of mechanical atomism in **section II**; an examination of the philosophical challenges facing mechanical atomism in **section III**; a discussion of the scientific challenges

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Toward Wisdom: An Interdisciplinary and Intercultural Introduction to Metaphysics (Indiana: University of Notre Dame Press, 2006), 23.

[36] Thomas Joseph White, *Wisdom In the Face of Modernity: A Study In Thomistic Natural Theology* (Florida: Sapientia Press of Ave Maria University, 2016), 24.

[37] David Bohm, *Causality and Chance In Modern Physics* (Philadelphia: University of Pennsylvania Press, 1957), 37.

facing mechanical atomism in light of both classical and quantum physics, centering especially on the subject of wholeness as highlighted by David Bohm in **section IV**; a discussion and synthesis of emergentism and Aristotelian-Thomistic philosophy as an alternative metaphysics to mechanical atomism in **section V**; a discussion and synthesis of the Bohmian interpretation together with emergentism and Aristotelian-Thomistic metaphysics in **Section VI**; a consideration of significant potential objections in **Section VII;** an exploration of the promises and implications of the present project in **section VIII**, and finally, the conclusion in **Section IX**.

Section II. On the History, Nature, and Key Characteristics of Mechanical Atomism

It is a delicate matter to examine broad metaphysical frameworks such as mechanical atomism in a critical fashion because they are often the result of a combination of empirical findings from science on the one hand, and interpretations of these findings in wider philosophical contexts (and beyond) on the other. In fact, physicist and historian of science Gerald Holton argues that the practice of science in any given period is always done in the context of certain themes or themata,[38] which, as elaborated by William A. Wallace, are "the fundamental presuppositions, methodological judgments and decisions, philosophical convictions, ideological and even theological views" within the context of which the findings of science are often interpreted and understood.[39] Holton models the complex relationship between science and themata via a three-dimensional Cartesian coordinate system in which the **x- axis** represents the experimental and empirical aspects of science, the **y- axis** represents the mathematical and theoretical aspect, and the **z- axis** represents the thematic aspect.[40] Applying Holton's analogy to his analysis of the history of causality and scientific explanation, the

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[38] Gerald Holton, "On the Thematic Analysis of Science: the Case of Poincaré and Relativity," in *Mélanges Alexandre Koyré* 2 (Paris: Éditions Hermann, 1964), 257-268.

[39] William A. Wallace, *Causality and Scientific Explanation*, *Vol.II: Classical and Contemporary Science* (Michigan: The University of Michigan Press, 1974), 241.

[40] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 241.

historian of science William A. Wallace argues that mechanical atomism is the definitive *thema* of modernity,[41] and mechanical atomism as such is characterized by **two major features**: **(1)** "the use of mechanical causes" and **(2)** "dominance of a Neoplatonic mathematicism"[42] that emphasise the mathematical above the physical. However, it is worth noting that mechanical atomism by no means arose from an intellectual vacuum because it is in fact the continuation[43] of certain strands of thoughts from late medieval Scholasticism.

Section II.1. Context: Aristotelian-Thomistic Hylomorphism: Matter as A Principle of Potentiality and Changeability.

Traveling back in time to the mid-twelfth to thirteenth century Europe, the rediscovery of Aristotle through The Corpus Aristotelicum has sparked a colossal intellectual struggle between the Latin Averroists and Augustinians because one of the key characteristic of Aristotelian philosophy is its critique of Plato. One of the most well known and significant disagreements between Plato and Aristotle is their differing conceptions of form and matter. Contrary to the transcendent status of Platonic forms, Aristotle[44] advances his own conception of form and matter as two interrelated mutual causes of things being what they are[45]: "[cause means] (i) An intrinsic feature [material]from which something is produced...(ii) The form and template, which is the account of the what-it-was-to-be-that-thing."[46]

Form and matter, or formal and material causes, are thus for Aristotle two interconnected principles *intrinsic* to existent things that are constitutive of their being. One crucial and often

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[41] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 255.
[42] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 255.
[43] Simpson ,"From Quantum Physics to Classical Metaphysics," 28.
[44] I follow Mariusz Tabaczek's very helpful references to Aristotle in this section on the topic of four causes. See Mariusz Tabaczek, "Emergence and Downward Causation Reconsidered In Terms of the Aristotelian-Thomistic View of Causation and Divine Action," *Scientia et Fides* 4, no. 1 (2016): 123. https://apcz.umk.pl/SetF/article/view/SetF.2016.010.
[45] Aristotle, *Physics*, ed. David Bostock, trans. Robin Waterfield (Oxford: Oxford University Press, 2008), II. 3, 194b23-28.
[46] Aristotle, *Metaphysics*, trans. Hugh Lawson-Tancred (London: Penguin Books, 2004), V, II, 1013a.

neglected feature of Aristotle's material cause, however, is that matter for him is ultimately a principle of potentiality and changeability, "(which is to say, something shape [or form]less), before it gains shape [or form]."[47] Aristotle's matter is thus not some ultimate small stuff everything is made of, but "what ultimately underlies [*τὸ πρῶτον ὑποκείμενον*] a thing"[48] as its "primary substratum,"[49] which, according to Aristotle, is always conserved because matter in this sense of primary substratum "does not cease to be"[50] but simply takes on different forms during transformation. For example, applying Aristotle's ideas, one could say that when a fundamental particle, such as a muon, transforms into other fundamental particles, such as an electron, a muon neutrino, and an electron anti-neutrino, the matter or primary substratum of the muon does not disappear; rather, it is conserved during this process of change and took on different forms, i.e., that of the electron, muon neutrino, and electron anti-neutrino.

As such, Aristotle's matter as primary substratum (or prime matter) is similar in significant aspects to the notion of energy in contemporary physics, which is likewise conserved and is convertible with matter in the usual sense of physical entities (which is 'second matter' in Scholastic terms). Energy as such is described by Einstein via the famous equation $E = mc^2$: something's intrinsic energy equals its mass times the speed of light squared, and the affinity between Aristotelian prime matter as primary substratum with energy in modern physics was noticed by one of the founders of quantum mechanics, Werner Heisenberg.[51] As such, Aristotle's

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[47] Aristotle, *Physics*, I. 7, 191a .
[48] Aristotle, *Physics*, I. 9, 192a .
[49] Tabaczek, "Emergence and Downward Causation," 124.
[50] Aristotle, *Physics*, I. 9, 192a .
[51] "The matter of Aristotle is certainly not a specific matter like water or air, nor is it simply empty space; it is a kind of indefinite corporeal substratum, embodying the possibility of passing over into actuality by means of form...the matter of Aristotle, which is mere 'potentia,' should be compared to our concept of energy." See Werner Heisenberg, *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper, 1958). See also David S. Oderberg, "Is Prime Matter Energy?" *Australasian Journal of Philosophy* (2022): 1-17. https://www.tandfonline.com/doi/full/10.1080/00048402.2021.2010222.

notion of matter as primary substratum underlies material reality as an ultimate matrix[52] that awaits the informing activity of form (*ὁ λόγος τοῦ τί ἦν εἶναι*), or "the statement of the essence, "[53] which, as foreshadowed by Aristotle in *De generatione et corruptione*, I,4, is further distinguished into substantial form, which causes the coming-to-be of a new substance, and accidental form, which is responsible for its accidental features[54] (more on this below in **Sections V and VI**).

Aristotle's view of form (*morphe*) and matter (*hyle*), which is now often referred to as hylomorphism, was systematically elaborated and defended in the thirteen century by St. Thomas Aquinas, who agrees with Aristotle that matter (*hyle*) in the ultimate sense of prime matter is "without any form and privation, but rather is subject to form and privation...by reason of the fact that there is no other matter before it. This is also called *hyle*, which means chaos or confusion in Greek.[55]

Section. II.2. The Medieval Roots of Mechanical Atomism: The Physicalization and Mathematization of Matter.

Aristotle and Aquinas' conception of matter and form as mutual causes of being, however, was rejected by some later Scholastic authors such as William of Ockham, who argued in the fourteenth century, via a theological voluntarism that emphasizes the absolute power of God and

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[52] William A. Wallace, *The Modeling of Nature: Philosophy of Science and Philosophy of Nature in Synthesis* (Washington: Catholic University of America Press, 1996), 9.

[53] Tabaczek, "Emergence and Downward Causation," 124.

[54] Tabaczek. "Emergence and Downward Causation," 125.

[55] Thomas Aquinas, *On the Principles of Nature to Brother Sylvester* [*De principiis naturae ad fratrem Sylvestrum*], trans. Kocourek, R. A. (St Paul: North Central Publishing, 1956), 14. Interestingly, Aquinas had a dynamic conception of matter as having the inclination to be informed by increasingly more complex and perfect forms, such that matter can first exist under "the form of an element," then "the form of a mixed body", then the forms or "vegetative soul[s]" of plants, then the forms or "sensitive souls" of the animals, and, eventually, the forms of "intellectual" souls of "human life."- Thomas Aquinas, *Summa Contra Gentiles*, trans.Vernon J. Bourke. (New York: Hanover House, 1955-1957), 22, 7. As such, it is remarkable that Aquinas' view of nature and its process of generation is not static - an impression often attributed to ancient and medieval authors unjustly, for evolution may not be such a surprise after all to someone like Aquinas, given his dynamic view of natural generation. See Mariusz Tabaczek, "An Aristotelian Account of Evolution and the Contemporary Philosophy of Biology," *Dialogo* 1, no. 1 (2014): 57-69. https://philarchive.org/archive/TABAAA-3.

the primacy of God's will, that there can be "no inherent necessity determining anything in the universe to be exactly as it is,"[56] such as the substantial forms, except God alone. As such, Ockham denies the reality of forms and 'universals' as they were conceived by Aquinas as intrinsic universal essences of things (they are of course created by God, for Aquinas), but holds instead that only "individual 'absolute things' (*res absolutae*)"[57] can have real existence, which, for Ockham, includes only substance and quality from Aristotle's categories.[58] One consequence of Ockham's position is that the rest of Aristotle's categories, such as quantity, action, passion, place, etc., all became nothing more than shorthand for talking about substance and quality, ultimately leading to Ockham's position that "quantity...became merely a term denoting either a substance or a quality," or in Ockham's own words: "there is no quantity different from substance or quality, just as there is no thing with part locally distant from part except a substance or a quality."[59] As such, substance, quality, and quantity became virtually indistinguishable in Ockham's *res absolutae*, which is without formal causation (at least in the sense of substantial form) due to his theologically motivated rejection of metaphysical universals. Thus, it is hard to see what is left in the ontological content of *res absolutae*, except perhaps the individuated particulars or physical stuff, a position characteristic of nominalism. Therefore, it is not surprising that Ockham, as Simpson (2022) points out, insists that "matter should have extension",[60] which amounts to a *physicalization* of the Aristotelian-Thomistic notion of matter.

One further consequence of Ockham's view is that since there is no difference between substance, quality, and quantity, the matter now becomes confused with their mathematizable

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[56] William A. Wallace, *Causality and Scientific Explanation. Vol.I: Medieval and Early Classical Science* (Michigan: The University of Michigan Press, 1972), 54.

[57] Wallace, *Causality and Scientific Explanation. Vol.I*, 54.

[58] Wallace, *Causality and Scientific Explanation. Vol.I*, 54.

[59] See *Summa totius logicae,* Pars 1, cap.49 as quoted in Wallace, *Causality and Scientific Explanation. Vol.I*, 54.

[60] Simpson, "From Quantum Physics to Classical Metaphysics," 28.

quantity, and vice versa. Such physicalization and mathematization of physical matter, however, "had little value for promoting an understanding of nature,"[61] and this was precisely another one of Aristotle's chief disagreements with Plato, that mathematics, without sufficient empirical and experimental investigation, does not automatically yield knowledge of nature: Ockham's own problematic attempts[62] at understanding natural phenomena like local motion ("whether uniform or accelerated"[63]) mathematically as mere coexistence of a body with different points of space that requires no cause[64] can perhaps serve as a cautionary tale for the significance of this Aristotelian insight. As such, Ockham's philosophy from the late medieval period already exhibits great resemblances with mechanical atomism, including a physicalization of matter as extended things in the form of *res absolutae* (which resembles Descartes' *res extensa* significantly), and a subsequent "dominance of a Neoplatonic mathematicism"[65] that emphasizes the mathematical above the physical, or mathematizes the physical.

Beside Ockham, Simpson (2022) identifies John Duns Scotus, who argues that matter ought to exhibit "actual parts,"[66] as well as Andre Dabillon the Ockhamist, who argues that "both matter and form are real substantial beings that exist actually in nature"[67] and some of the other medieval authors who have also contributed to the physical-mathematization of matter. One consequence of these tendencies to physicalize and mathematize matter in late medieval thought is that matter becomes increasingly separated from, and independent of, forms.[68] After all, if

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[61] Wallace, *Causality and Scientific Explanation*. *Vol.I*, 54.

[62] See Ockham's *Summa totius logicae*, pars 1, cap.49 as quoted in Wallace, *Causality and Scientific Explanation*. *Vol.I*, 55.

[63] Wallace, *Causality and Scientific Explanation*. *Vol.I*, .55.

[64] Ockham's *Summa totius logicae*, pars 1, cap.49 as quoted in Wallace, *Causality and Scientific Explanation*. *Vol.I*, 55.

[65] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 255.

[66] See Simpson, "From Quantum Physics to Classical Metaphysics," 28, which references to Scotus' *Reportatio*, II.12.2 n.7 (XI:322b).

[67] See Dabillon's *Physique*, I. 3.2., p.103 as referenced by Simpson, "From Quantum Physics to Classical Metaphysics," 28,

[68] Simpson, "From Quantum Physics to Classical Metaphysics," 28.

matter is already physicalized or actualized all by itself, there is then little causal work left for forms to do except to perhaps account for the quantifiable arrangement of matter (accidental forms), which are most likely reducible to the spatial relationships between different heaps of matter that result from their interaction. As a result, Aristotle's notion of matter was physicalized and mathematized, and increasingly seen as mere 'stuffs' that push and pull each other as efficient causes in disciplines such as kinematics within the late medieval themata of science (especially at Oxford amongst thinkers such as John Dumbleton and William Heytesbury, following the influence of Ockham[69]). This focus on material and efficient causes, however, came at the expense of neglecting the Aristotelian-Thomistic formal cause especially in the sense of substantial form, as well as its associated final causality as the state of completion or perfection of a substance given its substantial form.[70]

Section II.3 Mechanical Atomism as the Emphasis of Material and Efficient Causes and the Abandonment of Formal and Final Causes.

This emphasis of material and efficient causes at the expense of substantial form and final cause in late medieval and early modern periods is identified by Bohm as precisely another defining feature of mechanical atomism[71] as the 'themata' in which the practice of science was understood in those periods. Specifically, **efficient causality** was defined by Aristotle as "the original source of change or rest...[like]a producer causes a product and a changer causes a

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[69] In fairness, the development of mathematics might have required such a methodological over-simplification of the physical world (given the latter's complexity that still puzzles the scientists of even the 21st century) without which there might not have been a significant mathematical development at Oxford at all. However, such over-simplification of nature does also mean that whilst medieval science at Oxford fostered the mathematical component of modern science, it was not able to develop more advanced experimentation and a greater understanding of the physical nature, which requires the efforts of another medieval center of science: the University of Paris, in which Aristotelian science's emphasis of empirical investigation made a greater impact through minds such as St. Albert the Great and St. Thomas Aquinas. See Wallace, *Causality and Scientific Explanation. Vol.I*, p.59-64.

[70] Aristotle, *Physics*, II. 7, 198b4-9.

[71] Bohm, *Wholeness and the Implicate Order*, 15.

change."[72]An efficient cause is thus anything that 'effectively' produces an effect, and as Tabaczek points out,[73] Avicenna and Aquinas further extended Aristotle's efficient cause to include perfective, dispositive, auxiliary, and advisory efficient causes.[74] Efficient causality is therefore a multifaceted notion for Aristotle, Avicenna, and Aquinas because it potentially includes any kind of source that is capable of producing effects or changes of any type, and these sources can be physical, natural, or the human agent, etc.

Furthermore, **final causality** or teleology was defined by Aristotle as "what something is for...for example, the end of health may involve slimming or purging or drugs or surgical implements; they are all for the same end."[75] An end or telos is thus a cause for Aristotle because it is the reason for which something exists or is done. What is significant and often misunderstood about Aristotelian final cause or teleology in this sense, however, is that it is not a systematic inauguration of fatalism or some "pre-established harmony, acting at the present from the future. [Rather, teleology or final cause] is a distinct type of causation, a natural tendency of things to actualize their potencies, i.e. to realize what is proper to their nature"[76] toward their proper functioning, flourishing, and goodness. For instance, Aristotle states in the *Physics* that "a thing's nature involves purpose," which is to exist according to "what it is to be the thing, and that the thing is as it is because it is *better that way* - not better in any absolute sense, but better given what that particular thing actually is."[77]

In the *Metaphysics*, Aristotle too affirms this connection between goodness, purpose, and nature utilizing an example from Anaxagoras. In Book XII, Aristotle argues that the "**end** (τέλος

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[72] Aristotle, *Physics*, II. 3, 194b 29-31.
[73] Tabaczek, "Emergence and Downward Causation," 130.
[74] Aquinas, *Commentary on the Metaphysics of Aristotle*, Book V, Lesson 2, 766-769.
[75] Aristotle, *Physics*, II. 3, 194b32- 195a2.
[76] Tabaczek, "Emergence and Downward Causation," 131.
[77] Aristotle, *Physics*, II. 7, 198b4-9.

or telos)" of a thing, as "a principle", is its "good."[7879] For example, human nature, for Aristotle, involves a rational, deliberative, and free or voluntary faculty of choice named "*βούλησις*"[80](*boulesis*) or willing, which is "a [rational] longing for good."[81] Therefore, the telos or final cause of humans is, for Aristotle, to flourish as human beings through making voluntary and deliberative choices (via prudence or *Phronesis*), through *boulesis* and the intellect (*nous*) to cultivate and practice the virtues that are the perfective states of the various human faculties and the human person as a whole. As such, the final cause or teleology of human beings as their state of flourishing is defined famously by Aristotle as "activity of the soul in accord with virtue.[82] In its focal meaning, therefore, final cause or *telos* is "an intrinsic goal - the notion of having an end simply means that an organism has a natural tendency to function well, to "do well." Living well is our end, and the inclination to do well and live well is our natural teleology."[83] (More on Aristotle's and Aquinas' notion of freedom below in **Section VIII**).

Yet, within the nominalist late medieval and its subsequent atomistic-mechanical early modern ethos, both final causality in this fore-mentioned intrinsic sense, as well as substantial form are sidelined in favour of a "fragmentary"[84] picture of the world that emphasizes material cause as physicalized and mathematized matter, and efficient cause as laws that determine the behaviour of the materials. **Descartes**, for example, states in the *Principles of Philosophy*, "I

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[78] Aristotle's text in 1075a from Aquinas, *Commentary on the Metaphysics of Aristotle,* Book XII, 12.

[79] This understanding of the intrinsic connection between one's end and one's goodness in Aristotle is clearly recognized by Aquinas, who states: "A fourth is the final cause...This [latter] cause is also that for the sake of which a thing comes to be, and [which is] the good of each nature. - "*Quarta causa est finalis...Et hoc est etiam cuius causa fit aliquid, et quae est bonum uniuscuiusque naturae*." - Aquinas, *Commentary on the Metaphysics of Aristotle*, I, Lesson 4, 70.

[80] Thomas Aquinas, *Sentencia libri De anima (Commentary on Aristotle's De Anima)*, trans. Kenelm Foster and Sylvester Humphries (New Haven: Yale University Press, 1951), Book III, Chapter X.

[81] "Now **wish (*βούλησις*)** is a [rational] longing for good, for no one wishes for anything unless he thinks it is good."- Aristotle, *Rhetoric*, trans. JH Freese (Cambridge: Harvard University Press, 1926), 1369a8.

[82] Aristotle, *Nicomachean Ethics: Translated With Introduction, Notes, and Glossary by Terence Irwin* (Indianapolis: Hackett Publishing Company, Inc., 2019), I, C7, S15, p.10.

[83] Raymond J. Devettere, *Introduction to Virtue Ethics: Insights of the Ancient Greeks* (Washington: Georgetown University Press, 2002), 22.

[84] Bohm, *Wholeness and the Implicate Order*, 19.

have described this earth and indeed the whole visible universe as if it were a machine" via a consideration of "the various shapes and movements of its parts."[85] For Descartes, this universal machine is reducible to the sum of its microphysical particles in a way akin to the atomism of Democritus: "Democritus also imagined certain small bodies having various sizes, shapes and motions, and supposed that every sense-perceptible body is the upshot of assemblage and mutual interaction of these little corpuscles."[86] The significance of Descartes' mechanical atomism is that it permits a simplification of the physical universe into purely quantitative notions to which mathematics and calculations are easily applicable for the purpose of prediction and control.

Yet, Descartes' program also threatens to reduce all elements of corporeal reality to only its quantitative elements whilst eliminating all non-quantitative ones.[87] Briefly, since Descartes conceives the entire physical world as composed of nothing but small material corpuscles and their quantitative feature, such as "sizes, shapes, and motions,"[88] it follows for Descartes that all non-quantitative aspects of reality, such as qualities including " 'light', 'colour', 'smell', 'taste', 'sound', 'heat', 'cold', other tactile qualities—and even 'substantial forms'"[89] are all reducible to the corpuscles and their movement, which can "produce all the sensations in our soul" upon contact with our "nerves."[90]

Furthermore, due to Descartes' rejection of formal and final causations, efficient causation now becomes the sole explanation for all the interactions between the corpuscles in Descartes' universe. To begin, Descartes defines motion as follows: "A piece of matter or body moves if it goes from being in immediate contact with some bodies that are regarded as being at

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[85] René Descartes, *Principles of Philosophy*, ed. Jonathan Bennett, trans. John Cottingham, (Early Modern Texts: Jonathan Bennett, 2022), 64-65, https://earlymoderntexts.com/assets/pdfs/descartes1644.pdf.
[86] René Descartes, *Principles of Philosophy*, 70.
[87] René Descartes, *Principles of Philosophy*, 68.
[88] René Descartes, *Principles of Philosophy*, 69.
[89] René Descartes, *Principles of Philosophy,* 69.
[90] René Descartes, *Principles of Philosophy*, 69.

rest to being in immediate contact with other bodies."[91] Next, Descartes argues that there are two causes for motion in the universe[92]: The *first* is God, who is the creator of matter, motion, and rest. The *second* consists of "certain rules or laws of nature, which are the secondary and particular causes of the various motions we see in particular bodies."[93] These rules or laws are summed up by Descartes' as his Three Laws of Nature that govern all local motions in the physical universe.[94]

According to Descartes' *Principles of Philosophy*, therefore, the world is both atomistic and mechanistic in that it is reduced to a set of quantifiable corpuscles (the '**atomistic**' component) governed not by powers conferred upon them intrinsically by their natures or forms (the Aristotelian-Thomistic position), but by a set of "laws of nature" that somehow themselves exhibit causal efficiency and can thus, as mechanisms of the universal machine, regulate the motion of the corpuscles as parts of this machine (the '**mechanistic**' component).

One immediate "victim"[95] of this reductionistic Cartesian metaphysics is **Thomas Hobbes**, who nevertheless wished to retain an authentically Aristotelian conception of science as the study of *dioti* (the equivalent of *quid sit* in the Latin of the Scholastics): the causal knowledge of why something is the case.[96] Yet, Hobbes ultimately held, like Descartes, that formal and final causes "are nevertheless efficient causes,"[97] which, together with the material cause, compose 'the entire cause.' Moreover, Hobbes spells out one significant consequence of this mechanical conception of causality: if causation is solely governed by efficient causes acting upon material causes without any concern for the intrinsic natures or formal cause as well as the causal

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[91] René Descartes, *Principles of Philosophy,* 32.
[92] René Descartes, *Principles of Philosophy,* 32-33.
[93] René Descartes, *Principles of Philosophy*, 33.
[94] René Descartes, *Principles of Philosophy*, 33-34.
[95] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 17.
[96] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 18.
[97] From Hobbes's *Elements of Philosophy*, in the *English Works*, 11 vols. (London: John Bohm, 1839), Vol. 1, 131-132 as quoted in Wallace, *Causality and Scientific Explanation*, *Vol.II*, 21.

efficiencies or final causes of the entities involved within the causal process, then, causation becomes merely a matter of "necessary connection"[98] or laws such that "in whatsoever instant the cause is **entire**, in the same instant the effect is produced necessarily.[99] This mechanistic conception of causation thus contrasts significantly with the Aristotelian-Thomistic one, and this is captured vividly by Feser (2015).[100]

Section II.4 Summary and Analysis.

Thus far, we have seen that mechanical atomism originates from the late medieval nominalism's theologically motivated rejection of universals and substantial forms under Ockham, which resulted in a subsequent physicalization and mathematization of matter in late medieval thoughts. An understanding of matter and the entire physical universe as reducible to quantifiable microphysical parts governed by physical laws as the efficient causes of motion thus triumphed in the subsequent early modern period, at the expense of a rejection of the Aristotelian-Thomistic formal and final causations, under philosophers like Descartes and Hobbes. As such, mechanical atomism was to remain the most dominant worldview in the West (and beyond) for over four hundred years until the present time.

As a general metaphysical framework and worldview, therefore, mechanical atomism has influenced us for a very long time with very significant consequences. Fast forward to the twentieth century, many thinkers, including David Bohm, have come to observe that "from physics, mechanism has spread into other sciences and into almost all fields of human endeavor -

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[98] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 20.

[99] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 20.

[100] "No longer were material things to be understood as possessed of potentialities or potencies by virtue of which they were inherently directed toward the generation of certain effects. Rather, they were to be understood as inherently inert but related by mathematically expressible laws...where this law is, as it were, imposed from outside. A and B could in theory have been related by a very different law, or by no law at all. For A, B, and every other element of the world are, as Hume would put it, entirely "lose and separate."-Edward Feser, *Neo-Scholastic Essays* (South Bend: St. Augustine's Press, 2015), 68.

that is, the mechanistic attitude."[101] For Bohm, this mechanistic attitude is manifested most evidently within the fragmentation of human life, which has divided human knowledge into specialities, human society into separate "political, economic, racial groups," and our natural environment into "an aggregate of separately existent parts, to be exploited by different groups of people."[102]As such, mechanical atomism has encouraged a fragmentary worldview to the extend that "man ceases to regard the resulting division as merely useful or convenient and begins to see and experience himself and his world as actually constituted of separately existent fragments," causing the person to "break himself and the world up.[103]

One example of the application of this fragmentary mentality to humanity's self-understanding can be found in the works of the influential thinker Alex Rosenberg, who holds according to his "scientism"[104] that reality, including the "the chemical, biological, psychological, social, economic, political, cultural facts," is exhaustively reducible to the fundamental entities of particle physics like "fermions and bosons," and that anything that cannot be explained by them is "no fact after all,"[105] which leads Rosenberg to concludes that social sciences and humanities are mere "*post hoc* rationalizations"[106] of our otherwise completely physically determined behaviors that generate the illusions of self-consciousness and intentionality.[107]

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[101] Bohm, *Unfolding Meaning*, 2.

[102] Bohm, *Wholeness and the Implicate Order*, 2.

[103] Bohm, *Wholeness and the Implicate Order*, 3. This fragmentary mentality is also vividly captured by Robert C. Koons: "political and social phenomena reduce to individual psychology, individual psychology to biology (including neuroscience), biology to thermodynamics, thermodynamics to chemistry, chemistry to atomic physics, atomic physics to particle physics."- Robert C Koons, "Knowing Nature: Aristotle, God, and the Quantum," in *Knowing Creation: Perspectives from Theology, Philosophy, and Science*, ed. Andrew B. Torrance and Thomas H. McCall (Andrew B. Torrance and Thomas H. McCall, 2018), (16) 215-236.

[104] Alex Rosenberg, "The Disenchanted Naturalist's Guide to Reality," On the Human, November 23, 2021, https://nationalhumanitiescenter.org/on-the-human/2009/11/the-disenchanted-naturalists-guide-to-reality/.

[105] Alex Rosenberg, "Disenchanted Naturalism," Kritikos 12, (2015). https://intertheory.org/rosenberg.htm.

[106] Alex Rosenberg, "Disenchanted Naturalism."

[107] Alex Rosenberg, "Disenchanted Naturalism." For a similar view to that of Rosenberg's, see Azim F Shariff, Joshua D. Greene, Johan C. Karremans, Jamie B. Luguri, Cory J. Clark, Jonathan W. Schooler, Roy F. Baumeister, and Kathleen D. Vohs, "Free Will and Punishment: A Mechanistic View of Human Nature Reduces Retribution," *Psychological Science* 25, no. 8 (2014): (2)1564,

What is more, Bohm argues that this fragmentary worldview, though it has motivated incredible technological progress, has also contributed greatly to pressing issues such as "pollution, destruction of the balance of nature," as well as a "world-wide economic and political disorder, and the creation of an overall environment that is neither physically nor mentally healthy for most of the people who have to live in it," in which individuals have "developed a widespread feeling of helplessness and despair, in the face of... an overwhelming mass of disparate social forces, going beyond the control and even the comprehension of the human beings who are caught up in it."[108] Hence, Bohm argues that "the correctness and necessity of mechanism has to be evaluated and criticized, especially with regard to whether ... the actual state of knowledge in physics continues to sustain and support this view, as well as to whether or not alternative views are possible."[109] It is precisely to these tasks we shall now turn.

Section III. Philosophical Challenges Facing Mechanical Atomism.

III.1.1 A Threat to Scientific Knowledge? Causation as Necessary Connection.

One of the most challenging issues of mechanical atomism was in fact raised by early modern philosophers themselves, namely, its conception of causation as mere necessary connection, which in fact poses a surprising subsequent threat to the possibility of scientific knowledge. To begin, in his *Essay Concerning Human Understanding*, **John Locke** defines cause and effect as follows: "a *cause* is that which makes any other thing, either simple idea, substance, or mode, begin to be; and an *effect* is that which had its beginning from some other thing."[110] Now, Locke inherited Descartes and Hobbes's mechanistic conception of causation as a matter of certain effects following from the operation of certain efficient causes. Yet, Locke

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http://www.antoniocasella.eu/dnlaw/Shariff_2014.pdf in which it is argued that human actions are "akin to other natural phenomena" without free-will, such as mechanical systems like viruses and hailstorms.

[108] Bohm, *Wholeness and the Implicate Order*, 2.

[109] Bohm, *Wholeness and the Implicate Order*, 2.

[110] John Locke, *An Essay Concerning Human Understanding* (McMaster University: Faculty of Social Sciences, 2000), Book 2, chapter 26, 2, https://socialsciences.mcmaster.ca/econ/ugcm/3ll3/locke/index.html

notices that this conception of causation does not explain why such operations ever occur.[111]

After all, if causation is nothing more then the connection between 'an effect B begins to exist' when 'an (efficient) cause A is present,' then, one simply lacks any resource to explain how this connection between cause and effect came to be or why this connection is necessary, or if it is indeed necessary at all. Hence, Locke expresses a great skepticism concerning the human ability to understand and explain reality in general through a mechanical philosophy by stating, contra Descartes, that mechanical philosophy in fact highlights an "incurable" ignorance, that is, "there is no discoverable connexion between any secondary quality and those primary qualities which it depends on."[112] This inability to discover the connection between primary and secondary qualities leads Locke to a further claim that humans might never be able to discover the causal necessities between the qualities and powers of things because though Locke endorsed the "corpuscularian hypothesis" of mechanical philosophy, he nevertheless does not think that, "with those faculties we have, we shall ever be able to [recognize which] … qualities and powers of bodies have a necessary connexion or repugnancy one with another."[113]

Causation thus becomes a mystery for mechanical atomism with the ontological basis of its necessary connections between cause and effect nowhere to be found. Locke concludes therefore that we have "no ideas of the particular mechanical affections of the minute parts of bodies that are within our view and reach, we are ignorant of their constitutions, powers, and operations,"[114] and that "we must be content to be ignorant of their properties and ways of operation."[115] The mechanical philosophy's ignorance of the causal knowledge of the material

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[111] "For to have the idea of cause and effect, it suffices to consider any simple idea or substance, as beginning to exist, by the operation of some other, without knowing the manner of that operation."- Locke, *An Essay Concerning Human Understanding*, Book 2, chapter 26, 2.

[112] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter 3, 12, p. 206.

[113] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 16.

[114] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 26

[115] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 25.

world thus presents a grave issue for Locke because it entails that we do not have the general knowledge of the natures of things and why they behave the way they do,[116] which for Locke means that we do not have the "scientifical...general, instructive, unquestionable truths concerning them."[117] From a Lockean perspective, the culmination of this series of failures of mechanical atomism in accounting for causation and the general truth about the natures and operations of material things thus ultimately marks a failure of humanity in obtaining scientific knowledge of the world: "Hence no science of bodies [is] within our reach...how far soever human industry may advance useful and experimental philosophy in physical things, scientifical will still be out of our reach,"[118] and that "as to a perfect science of natural bodies...I conclude it lost labour to seek after it."[119] As to the 'necessary' connections between cause and effect, Locke states "we can attribute their connection to nothing else but the arbitrary determination of that All-wise Agent who has made them to be, and operate as they do."[120]

Locke thus prophesied with great acuity here the future impact of the mechanical-atomist metaphysics, which will go on to foster great technological progress whilst encouraging a pragmatic 'shut-up and calculate' approach to science[121] that is still far from giving sufficient emphasis to what Locke would consider a scientific knowledge of nature, that is, the knowledge of the "causes, manner, and certainty of their production"[122] of things.

After Locke, **George Berkeley** too questioned mechanical atomism's ability to

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[116] Except in "particular matter of fact" that we can discover through experimentation, which Locke argues in anticipation to Hume that "whether they will succeed again another time, we cannot be certain.) See Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 25.

[117] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 26.

[118] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 26.

[119] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 29.

[120] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 28. Here, one encounters the ghost of Ockham, whose voluntarism and nominalism still haunt science with its insistence that there is no inherent universal necessity or intelligibility in nature for science to discover, but all is subjected to the arbitrary will of a voluntary deity.

[121] Recall Bohm's claim that western academia's has emphasized "calculation," and "experimental results" at the expense of an emphasis on the philosophical implications of science - Bohm, *Unfolding Meaning*, 7.

[122] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 29.

understand and explain reality in a scientific fashion. Like Locke, Berkeley thinks that 'necessary connection' can only be used as a kind of pragmatic law or rule without revealing to us the nature of causation and thus the true workings of the universe. Unlike Locke, however, Berkeley went even further in his critique of mechanism by claiming that the categories of mechanical philosophy, including "gravity," and "force," are all "occult qualities" that have been "taken in vain as the principle of motion."[123] As such, Berkeley turns the table on his contemporary mechanical philosophers for it is one of the key characteristics of mechanical philosophy that it wishes to depart from the so-called occult qualities of medieval philosophy and explain reality via concrete and quantifiable features of the world like gravity and force. Yet, Berkeley claims that these mechanical notions are in fact themselves occult qualities, and "What itself is occult explains nothing."[124] Hence, Berkeley suggests that one ought to think of them as useful "mathematical hypothesis" and "abstractions" even though they do not reveal "the natures of things."[125]

Berkeley thus quite precisely points out one important consequence of mechanical atomism's treatment of matter as mere passive materials to be acted upon by mathematically expressible laws: without notions such as the nature, qualities, and powers of real physical things, the laws themselves now tend to be seen as real entities by mechanical philosophers like Descartes, who thought his laws of nature exhibit real causal efficiency as causes of motion. Yet, Berkeley notes that these laws seem to be only hypothetical abstractions that have no reality in themselves except as a kind of hypotheses or model for how material things appear to operate without disclosing their "natures."

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[123] George Berkeley, *De Motu and The Analyst: A Modern Edition, with Introductions and Commentary* (Berlin: Springer Science & Business Media, 2012), 74-75.

[124] Berkeley, *De Motu and The Analyst*, 75.

[125] Berkeley, *De Motu and The Analyst*, 103.

As such, Berkeley went on to apply his critique to the key principles of Newtonian mechanics by arguing that although "Action and reaction are said to be in bodies; and this is quite convenient in mechanical demonstration," we nevertheless "should beware not to suppose for this reason that some real power is in them which is the cause or principle of motion" because action and reaction is "only a mathematical hypothesis and not a physical quality."[126] Moreover, Berkeley argues, echoing Locke,[127] that though "the mechanical philosophy" utilizes "the truth and use of the theorems of the mutual attraction of bodies," we nevertheless cannot know how this attraction come to be, or "whether this motion is supposed to be caused by the action of bodies mutually attracting each other or by the action of some agent distinct from bodies impelling and controlling them... or in an incorporeal agent."[128]

As Berkeley sees it, therefore, mechanical philosophers' ideal to explain reality scientifically without recourse to the formal and final causes of things (which are central to the Aristotelian-Scholastic conception of science) but solely through the necessary connections between efficient and material causes ultimately failed because, as it turns out, we cannot really identify the true efficient causes in nature since we do not know how and why causal connections ever occur except that they do. Consequently, Berkeley restricts science to only an instrumental and descriptive role[129] because "the mechanical philosophers never explained any thing; their province being only to discover the laws of nature, that is the general rules and method of motion, and to account for particular phenomena by reducing them under, or showing their conformity to

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[126] Berkeley, *De Motu and The Analyst*, 85.

[127] "For to have the idea of cause and effect, it suffices to consider any simple idea or substance, as beginning to exist, by the operation of some other, without knowing the manner of that operation…" - Locke, *An Essay Concerning Human Understanding*, Book 2, chapter 26, 2.

[128] Berkeley, *De Motu and The Analyst*, 85.

[129] "it is the concern of the physicist or mechanician to consider only the rules, not the efficient causes, of impulse or attraction." - Berkeley, *De Motu and The Analyst*, 89.

such general rules."[130] These 'rules,' however, were still unreliable for Berkeley because their truth "depend on a supposition that the Author of nature always operates uniformly, and in a constant observance of those rules we take for principles: which we cannot evidently know."[131]

Locke and Berkeley's critique of mechanical atomism's conception of causation will be picked up by **David Hume**, who followed his predecessor's critique to its logical conclusion[132] by declaring that one "never can...discover anything but one event following another, without being able to comprehend any force or power by which the cause operates, or any connexion between it and its supposed effect.[133] What of the fact that the progress of experimental science and technology nevertheless depends on the use of causal reasoning and laws of nature as if they are real features of reality? Hume's reply to this question in a famous passage of the *Enquiry*, however, was (unsurprisingly) bewildering: causal "connexion[,] ... this customary transition of the imagination from one object to its usual attendant, is the sentiment or impression from which we form the idea of power or necessary connexion. Nothing farther is in the case."[134]

Therefore, 'necessary connection,' for Hume, turns out to be not an inherent feature of the world at all, but merely a construct of psychological habit created by our mind once it has perceived many similar instances in which certain events are constantly connected. Causation, therefore, is nothing but an imagination of our mind that does not capture any real feature of the world. Given this psychological conception of causation, therefore, it is not surprising that Hume

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[130] George Berkeley, *Siris: A Chain of Philosophical Reflexions and Inquiries Concerning the Virtues of Tar Water* (Google Books: Google, 2022), 108, https://www.google.ca/books/edition/Siris_a_Chain_of_Philosophical_Reflexion/58xbAAAAQAAJ?hl=en&gbpv=1&printsec=frontcover,

[131] From Berkeley's *A Treatise Concerning The Principles of Human Knowledge* as quoted in Wallace, *Causality and Scientific Explanation*, *Vol.II*, 37.

[132] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 44.

[133] David Hume, *An Enquiry Concerning Human Understanding* (Hamilton: McMaster University, Faculty of Social Sciences, 2022), Section VII, Part II, 58, https://socialsciences.mcmaster.ca/econ/ugcm/3ll3/hume/enquiry.pdf), Emphasis added.

[134] David Hume, *An Enquiry Concerning Human Understanding*, Section VII, Part II, 59.

famously rejects the ancient Aristotelian Principle of Causality by claiming that even contingent things that begin to exist might not have a cause at all (which violates the principle of the conservation of energy in modern physics, especially as it is found within quantum field theory) since if the connection between cause and effect is merely a product of imagination, one can just as easily separate cause and effect with one's imagination.[135]

III.1.2. Summary, Analysis, and Conclusion

Far from explaining all physical phenomena scientifically as 'necessary connection' between quantifiable corpuscles, therefore, mechanical atomism's conception of the world has now, under the critique and exposition of Locke, Berkeley, and Hume, quite literally become a figment of our imagination, a turn of event that was "bringing the empiricist program to the verge of absurdity,"[136] which seems most bewildering in the face of the unparalleled success of modern science. For it seems plainly unreasonable that the detailed knowledge we have of the characteristics, workings, and interactions of the great many things of nature from the distant stars down to the subatomic realm should be nothing more than a fable of our mind, for indeed, as it is often argued, that it would be a miracle that science actually "works" if our knowledge of the world are mere imaginations.

Even more fundamentally, mechanical atomism's conception of causation as necessary connection in fact endangers the very epistemological foundation of scientific knowledge itself as classically defined by Aristotle in *Posterior Analytics*: the knowledge of the "true, immediate, and proper"[137] causes of things. This Aristotelian causal approach to scientific knowledge, which formed the backbone or themata of scientific practice in the Latin West during the high medieval

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[135] David Hume, *A Treatise of Human Nature, by David Hume; Reprinted From the Original Edition in Three Volumes and Editions, with An Analytical Index*, ed. L. A. Selby-Bigge (Oxford: Clarendon Press, 1951), 79.

[136] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 45.

[137] James A. Weisheipl, *Aristotelian Methodology: A Commentary on the Posterior Analytics of Aristotle*, ed. John R. Catan (River Forest: Dominican House of Studies, Pontificial Institute of Philosophy, 1958).

period especially in the University of Paris under St. Albert and St. Thomas Aquinas, was inherited by key early modern scientists like **Newton**, who, in his four "Rules of Reasoning in [Natural]Philosophy"[138] found in Book III of his *Mathematical Principles of Natural Philosophy*, acknowledges that the enterprise of science is a search for "causes...true and sufficient[139] that explain the phenomena of nature, and he has laboured intensely to discovery the true causes of natural phenomena like gravity and the prismatic dispersion of white light into a spectrum.[140] Yet, a search for true causes becomes impossible under atomistic-mechanical philosophy since, as demonstrated by Descartes and Hobbes, it treats matter as causally inert materials to be acted upon by physical laws such that when a 'cause' is present, an 'effect' comes to be via a 'necessary connection', leaving the precise reason and explanation for why such connection occur nowhere to be found in the physical world. Later thinkers such as Locke, Berkeley, and Hume were thus scandalized and concluded that if causation is nothing more than necessary connection, then, "no science of bodies [is] within our reach"[141] and that science should give up the search for causality altogether and merely treat it as a useful "imagination."[142]

As such, the issue of scientific knowledge created by mechanical atomism will go on to scandalize many more great minds, including **Immanuel Kant**, who laboured with great intensity to rescue the philosophical foundation of scientific knowledge from Hume, but only ended up conceding still that what the human person can know about reality "has to do only with appearances, and must leave the thing in itself as indeed real *per se*, but as not known by us"[143]

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[138]Isaac Newton and N. W. Chittenden, *Newton's Principia: The Mathematical Principles of Natural Philosophy* (New York: Geo. P. Putnam, 1850), 384-385. Emphasis added.

[139] Isaac Newton, *Isaac Newton's Papers and Letters On Natural Philosophy*, ed. Bernard Cohen and Robert E. Schofield (Cambridge, Massachusetts: Harvard University, 1958), 51.

[140] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 197-205.

[141] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 26.

[142] Hume, *An Enquiry Concerning Human Understanding*, Section VII, Part II, 59.

[143] Immanuel Kant, *Immanuel Kant's Critique of Pure Reason*, trans. N. K. Smith (New York: St. Martin's Press, 1965), Bxx, 24 as quoted in Wallace. *Causality and Scientific Explanation*, *Vol.II*, 67.

thereby paving the way for the so-called post-modernity (more properly called ultra-modernity) in which thinkers like Saussure and Derrida express little more than an ultra-radicalization of the fundamental modern philosophical ethos that "the whole of human awareness is a construction of the human mind."[144]

As such, the mechanical philosophy's difficulty to account for scientific knowledge constitutes a great challenge to the credibility of mechanical atomism because it suggests that mechanical atomism's account of reality is incomplete insofar as it cannot account for those aspects of reality, especially causation, that many scientists rightfully recognize as intelligible and real. We shall explore precisely this subject in the following section.

III.2. An Incomplete Account of the Physical Universe? The Problem of Justifying Reductionism.

Newton, though a hero to mechanical science, was acutely aware that the mechanics cannot give reality an exhaustive description, and Newton demonstrated this awareness when he distinguished his mathematical-mechanical model of physical things from the physical things themselves in the *Principia*. For example, when defining motive, accelerative, and absolute forces in the *Principia*, Newton states that they must be "endued with some cause" that explain why these forces have been "propagated through the spaces round about"[145] even though the identification of these true causes is not within Newton's scope of consideration when he was formulating a mathematical notion of these forces. For example, Definition VIII of the *Principia*: "The motive quantity of a centripetal force, is the measure of the same proportional to the motion which it generates in a given time.[146] What is noteworthy here is Newton's awareness that he is "design[ing] only to give a mathematical notion of those forces, without considering their

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[144] John Deely, "On 'Semiotics' as Naming the Doctrine of Signs," *Semiotica*, no. 158 (2006): 10.
[145] Newton and Chittenden, *Newton's Principia*, 76.
[146] Newton and Chittenden, *Newton's Principia*, 76.

physical causes and seats,"[147] which are not captured by the mechanical laws but lie beneath the laws in real and concrete physical reality. Newton was thus consciously aware that the mechanics he was developing do not provide a full and exhaustive description of the physical universe because mechanics is concerned only with providing a mathematical model for those aspects of the world that are quantifiable, which *leaves out* any non-quantifiable aspects of the world, such as the "physical causes and seats" of attractive forces. What, then, might these non-quantitative features of the world be?

Newton answers, to many of his contemporary mechanical philosophers' surprise, that there exist irreducible *qualities* in nature beyond the quantitative scope of mechanism, and this thesis was first forwarded by Newton in his *Philosophical Transactions* that the "true cause" of prismatic dispersion of a light beam is that "light consists of ray differently refrangible, which ... transmitted towards divers parts of the wall."[148] Furthermore, Newton states that "colours are...**original and connate properties**, which in divers [diverse] rays are divers." [149] Newton thus conceived colour as a "true property"[150] "connate" or intrinsic to the rays of light. This conclusion of Newton's invoked a wave of criticism toward him from "such eminent scientists as Robert Hooke and Christiaan Huygens, and by French and English Jesuits on the Continent" because they conceived Newton as exhibiting the "peripatetic[Aristotelian] tendencies"[151] of Aristotelian-Scholasticism by preferring to explain colour as a quality rather than subscribing to the purely quantitative method of Cartesian mechanism. Newton's reply to these criticisms, however, was firm in their disposition: "I never intended to show wherein consists the nature and difference of colours, but only to show that *de facto* they are *original and immutable qualities* of

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[147] Newton and Chittenden, *Newton's Principia*, 76. Emphasis added.

[148] Isaac Newton, *Isaac Newton's Papers and Letters On Natural Philosophy*, ed. Bernard Cohen and Robert E. Schofield (Cambridge, Massachusetts: Harvard University, 1958), 51.

[149] Newton, *Isaac Newton's Papers and Letters On Natural Philosophy*, 53.

[150] Wallace, *Causality and Scientific Explanation*. *Vol.I,* 199.

[151] Wallace, *Causality and Scientific Explanation*. *Vol.I*, 199-200.

the rays which exhibit them,"[152] so writes Newton in a letter to Huygens.

Newton's commitment to the existence of qualities also manifests in his treatment of gravity, which he defines as the following in Proposition VII, Book III of the *Principia*: "That there is a *power* of gravity tending to all bodies, proportional to the several quantities of matter which they contain."[153] Newton's formulation of gravity was famously accused of reviving the 'occult quality' of Aristotelian-Scholasticism' by Leibniz, who writes in a 1715 letter to Abbe Conti: "His [Newton's] philosophy appears to me rather strange and I cannot believe it can be justified. If every body is heavy, it follows...that Gravity will be a scholastic occult quality or else the effect of a miracle."[154] Newton's response to the kind of criticisms raised by Leibniz, however, was multifaceted. Firstly, Newton distinguishes between *occult qualities* and *manifest qualities* in a reply to Leibniz: "As for Philosophy, he [Leibniz] colludes in the signification of words ... calling those things occult qualities whose causes are occult, though the qualities themselves be manifest."[155] But even before this, Newton has added *a definition of quality* in a second edition of the *Principia* published in 1713:

> RULE III. The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.[156]

With this definition, Newton identifies certain basic and observable qualities and attributes them to all material bodies, including "extension, hardness, impenetrability, mobility, and *vis inertiae*," calling them the "foundation of all philosophy."[157] Towards the end of the same section, however, Newton applies the same reasoning to gravity, arguing that "if it universally

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[152] Wallace, *Causality and Scientific Explanation*. *Vol.I*, 199-200.
[153] Newton and Chittenden, *Newton's Principia*, 397.
[154] See Alexandre Koyré, *Newtonian Studies* (Cambridge, Ma.: Harvard University Press, 1965), 144.
[155] Koyré, *Newtonian Studies*, 144.
[156] Newton and Chittenden, *Newton's Principia*, 384. Emphasis added.
[157] Newton and Chittenden, *Newton's Principia*, 385.

appears, by experiments and astronomical observations, that all bodies about the earth gravitate towards the earth ... we must, in consequence of this rule, universally allow that all bodies whatsoever are endowed with a principle of mutual gravitation."[158] Is Newton then suggesting that gravity is a kind of quality akin to extension, hardness, etc.?

Although Newton did not claim so explicitly, his close colleague Roger Cotes notably argued in affirmation of this interpretation in a preface he wrote to the second edition of Newton's *Principia* as the latter's editor and proofreader: "those are indeed occult causes whose existence is ... not proved; *but not those whose real existence is clearly demonstrated by observations.* Therefore gravity can by no means be called an occult cause ... *because it is plain from the phenomena that such a power does really exist*..."[159] What is significant about Newton and Cotes' position is that they affirm the existence of real or manifest qualities endowed with real causal power, which is in continuity with the classical Aristotelian-Scholastic philosophy of nature and in contradiction to the modern mechanistic one (which has led to the Cartesian philosophers' attempts to explain gravity mechanically via "imaginary vortices of matter"[160] rejected by Newton).

Now, quality was amongst the famous Ten Categories of Aristotle, and Aquinas understands the Categories as particular manners or modes (*modum essendi*)[161] via which being may be said to exist.[162] The categories thus signify the intelligibly distinct modes of *being* (*ens*), which, for Aquinas, can either exist in itself as substantial being (*esse*), like a tree, or exist in

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[158] Newton and Chittenden, *Newton's Principia*, 385.
[159] Koyré, *Newtonian Studies*, 142.
[160] Koyré, *Newtonian Studies*, 142.
[161] Thomas Aquinas, *Questiones Disputatae De Veritate*, trans. Robert W. Mulligan, S.J., James V.McGlynn, S.J., and Robert W. Schmidt, S.J. (Chicago: Henry Regnery Company, 1954), Q.21, a. 1, *Responsio*.
[162] Nicholas Kahm, "Aquinas on Quality," *British Journal for the History of Philosophy* 24, no. 1 (2016): (3)23-44.

another as accidental being (*inesse*), such as the various properties and features of the tree.[163] Quality, for Aristotle and Aquinas, is therefore an accidental being[164] that exists within substances as "certain determination" or "mode"(*Modus*)[165] of those substances. Thus, quality signifies *how* a substance is by signifying its determinations, which is distinct from quantity, which signifies *how much* a substance is.

Aquinas also distinguishes quality into *four species* according to different measures, following Aristotle: **(1):** When measured by the *"nature" (form and matter)* of a substance, quality is the "*habit and disposition*"[166] of that substance, since it determines *how* the substance is in general, and this is the *first* species of quality. **(2&3):** When measured by the "action or passion"[167] of a substance, "we have the *second* (*capacity and incapacity*) and *third* (*passion and sensible qualities*) species"[168] of quality, since they determine *how* the substance is in its causal interaction with other things. **(4):** When measured by the "*quantity*"[169] of a substance, quality is the "form and figure"[170] of the substance, since it determines the physical shape of that substance.

As such, Roger Cotes' interpretation of Newton's notion of *gravity* as a manifest quality of material bodies and Newton's explicit understanding of colour as a quality would, respectively, fall under Aquinas' second and third species of quality. Let's briefly discuss them in turn. Aristotle's and Aquinas' *second species of quality* refers to the "natural power or natural impotence (*potentia vel impotentia naturalis*)"[171] with which a substance is capable or incapable

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[163] Kahm, "Aquinas on Quality," (4)23-44.
[164] Kahm, "Aquinas on Quality," (7)23-44.
[165] "For quality, properly speaking, implies a certain mode of substance...wherefore it implies a certain determination according to a certain measure..." - Thomas Aquinas, *Summa Theologiae*, trans. In Fathers of the English Dominican Province (Ohio: Benziger Bros, 1951), I-II, q.49, a.2
[166] Aquinas, *Summa Theologiae*, I-II, q.49, a.2.
[167] Aquinas, *Summa Theologiae*, I-II, q.49, a.2.
[168] Kahm, "Aquinas on Quality," (8)23-44, 8.
[169] Aquinas, *Summa Theologiae*, I-II, q.49, a.2.
[170] Kahm, "Aquinas on Quality," (8)23-44, 8.
[171] Thomas Aquinas, *On Spiritual Creatures (De Spiritualibus Creaturis)*, trans. Mary C. FitzPatrick and John J. Wellmuth (Milwaukee, Wisconsin: Marquette University Press, 1949), 11, Respondeo.

of doing something.[172] Gravity, on Cotes' interpretation, would be a quality or power (*potentia naturalis*) of material bodies of this second species to attract other material bodies toward them. This "quality-based" approach to gravity in fact becomes promising again with the subsequent development of field theory in physics since Newton's time. For instance, the renowned physicist Anthony Rizzi (who specializes in the detection of gravity waves) from Caltech, explains gravity as a "*power* that permeates the region around a passive body...Gravity is a power (capacity) to activate impetus, a *quality* ... We say gravity is a property, in the category of *quality*, of "space"[that is, the "*plana*" or region around the Earth that gravity is a quality of]."[173]

Furthermore, Newton's qualitative notion of *colour* would at first appear to fall under Aristotle's and Aquinas' third species of quality as *passion and sensible qualities*[174] because sensible qualities like colour are understood by Aquinas as "passive quality" for the power of sensation is understood by Aquinas as a "passive power" (*potentia passiva*),[175] since it results from the external sensible thing's contact with the sensory organs, which leaves "imprints" (*species impressae*) on the organs that passively receive them, such as when sound contacts the eardrum, or when light meets the retina in the eye,[176] resulting in the *proper sensibles* such as colour, sound, smell, etc. However, this implies that the sensible things themselves would too exhibit some active powers or qualities with which they can act upon the sensory organs, and this is pointed out by Aristotle in chapter 8 of the *Categories*: sensible qualities are "called affective not because the things that possess them have themselves been somehow affected ... but it is because each of the qualities mentioned is productive of an affection of the senses that they are

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[172] "*per potentiam sumus potentes aliquid facere*" - Thomas Aquinas, *Summa Contra Gentiles*, trans. Vernon J. Bourke (New York: Hanover House, 1955-1957), IV, 77, 4.

[173] Anthony Rizzi, *Physics for Realists: Mechanics. Modern Physics with a Common Sense Grounding* (Baton Rouge, LA: IAP Press, 2008), 375-376. Emphasis added.

[174] Aquinas, *Summa Theologiae*, I, q.77, a.3.

[175] Aquinas, *Summa Theologiae*, I, q.78, a.3.

[176] Aquinas, *Summa Theologiae*, I, q.77, a.5.

called affective qualities."[177]

Colour, as Newton understood it, thus seems to be referring to Aristotle's *affective* sensible qualities intrinsic to the varying degrees of frangibility of the different rays of light, which difference we now understand as electromagnetic radiation having different wavelengths, and different wavelengths present to us as the different colours that Newton called "original and immutable qualities;"[178] for example, light with a wavelength of 550 nanometers (nm) looks green, 580 nm looks yellow, 700 nm looks red, etc. Now, these electromagnetic radiations are capable of causally acting upon the retina in our eyes, which exhibit light-sensitive cells or receptors that allows us to visually detect and receive these radiations passively as colour.

Despite his affinity with Aristotelian-Scholastic philosophy, however, Newton did voice his disagreement with the Aristotelians of his day.[179] Specifically, Newton distinguishes between "**manifest qualities"** and "**occult qualities**,"[180] and he criticizes the Aristotelians of his day for hindering the advance of science by inventing occult qualities to explain the cause of phenomena like gravity. Nevertheless, Newton, in accepting the existence of manifest qualities like colour and gravity as distinct from and irreducible to quantity, stands in an undeniable continuity with the boarder philosophical framework of Aristotle and Aquinas passed down by the Scholastics and in contradiction with mechanical atomism as conceived by early moderns like Descartes, who as we have seen thought that all features of the physical universe are reducible to quantities. One may thus argue that what Newton was fundamentally opposing was not the essential methodology of Aristotelianism (which is based on an empirical search for the proper and true causes of natural phenomena without which science becomes impossible), but rather the way it

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[177] Translation by Kahm, "Aquinas on Quality," (12)23-44.
[178] Wallace, *Causality and Scientific Explanation*. *Vol.I*, 200.
[179] From the *Opticks* of Newton as quoted in Koyré, *Newtonian Studies*, 145.
[180] From the *Opticks* of Newton as quoted in Koyré, *Newtonian Studies*, 145.

was practiced by many of its practitioners in the sixteenth and seventeenth centuries.

III.3. Analysis and Conclusion.

As such, the key philosophical and methodological characters of modern science, as exemplified by the thoughts of Newton, has a few crucial implications in relation to our evaluation of the credibility of mechanical atomism.

Firstly, Newton's conception of science in fact illustrates a *linkage* often overlooked by the modern philosophers between the "*new science*" of the modern era and the perennial *Aristotelian conception of science*, that is, both parties conceive the enterprise of science as, first and foremost, a search for what the Aristotelian-Scholastics like Aquinas call the *proper cause* (*propria causa*[181]*),* or what Newton calls the "*true cause*"[182] of phenomena in the natural world. Newton was devoted to precisely such a project of science in his search for the true causes of the movement of celestial bodies and prismatic dispersion.

Secondly, Newton's (1) insistence via the Aristotelian-Scholastic tradition that there exist irreducible *qualities* in nature and (2) his identification of these qualities (such as colour and gravity) as the true causes of natural phenomena constitute a great challenge to mechanical atomism's claim to give the physical reality an exhaustive description with only quantitative notions. Specifically, mechanical atomism conceives causation quantitatively as mere regular 'necessary' connections of certain events as rules or laws of nature. Yet, as we have seen, this approach to causation is incapable of accounting for the kind of true causes that Newton is looking for because, as demonstrated by Locke, Berkeley, and Hume, we cannot know why these connections ever occur except that they do within the scope of mechanical atomism, which further entails that we also cannot be certain if these connections will suddenly stop from

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[181] See Aquinas, *Summa Theologiae*, I-II, q.32, a.1.
[182] Newton, *Isaac Newton's Papers and Letters On Natural Philosophy*, 51.

happening, which is famously pointed out by Hume with his example of the sun rising. For Newton, however, this inability of mechanical atomism to account for true causes would amount to a failure to account for the very possibility of scientific knowledge because without any way of locating the true causes, one can never hope to truly explain the occurrence of natural phenomena scientifically: Feser (2019) puts this issue transparently.[183]

A Newtonian correction to mechanical atomism's inability to account for true causes, however, is to affirm that there exist irreducible and 'manifest' qualitative features of the world with real causal power (as in Aristotelian-Thomistic philosophy) that can induce change on other objects in nature, and identify these qualitative features as the true causes and thus our scientific explanation of certain natural phenomena. For example, the movement of celestial bodies such as those described by Kepler's law of planetary motion was explained by Newton via gravity as a quality or power: "Hitherto we have explained the phenomena of the heavens and of our sea by the **power of gravity**...it is enough that gravity does really exist...and abundantly serves to account for all the motions of the celestial bodies, and of our sea."[184] Newton's identification of qualities as true causes and thus the seats of scientific knowledge, however, would contradict a key assumption of mechanical atomism that the entire physical world is reducible to its quantitative features and their movements.

As such, it seems that mechanical atomism faces a conundrum: either it is false as demonstrated by Newtonian science, or it can deny the Aristotelian-Newtonian definition of

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[183] "But there is an even deeper and more serious problem with the regularity theory of laws of nature, however many qualifications we add to it. The problem is that if a physical law is a mere regularity, then it doesn't really explain anything. All it does is re-describe things. Suppose you say: "Planets always move in elliptical orbits. I wonder what explains that?" Suppose I answer: "Kepler's first law explains that." You then ask: "oh, how interesting. What is Kepler's first law?" And I respond by telling you that Kepler's first law states that planets always move in elliptical orbits. Obviously, we've gone around in a circle. I haven't really explained the regularity in question at all, but merely slapped the label "law" on it." Edward Feser, *Aristotle's Revenge: The Metaphysical Foundations of Physical and Biological Science* (Germany: Editiones Scholasticae, 2019), 183.

[184] Newton, and Chittenden, *Newton's Principia*, 506-507. Emphasis added.

science as knowledge of true causes and reduce science to a mere instrumental role like Berkeley did, which trivializes science. Newton, however, offers a reasonable solution to this dilemma by admitting that mechanical atomism is true but only in a *limited* sense. After all, it is true that a great deal of the physical universe can be powerfully explained and controlled quantitatively, but this fact does not by itself entail that quantity is the only real feature of nature, and this was pointed out clearly by Newton: in answering Leibniz's charge that if gravity is conceived in a Newtonian fashion as a "primitive quality or by a law of God" that cannot be explained mechanically, then, it must be "an occult quality,"[185] Newton replies that there are phenomena, such as *vis inertiae*, etc., that are "natural, real, reasonable, manifest qualities of all bodies seated in them by the will of God from the beginning of the creation and *perfectly incapable of being explained mechanically*."[186]

As such, mechanical atomism's claim to reduce the whole of physical reality to its quantifiable elements is denied by Newton, the very hero of mechanical science himself, both with science and supposedly 'suspicious' Aristotelian-Scholastic notions of "quality", "power", and "substance" no less. Despite Newton's repeated fair warning, however, the enthusiasm of modernity for the technical mastery of nature and a breaking away from the influence of Aristotle and Catholicism fueled by the religious and political zeal following the protestant reformation will carry mechanical atomism along eventually to its crowning glory as a philosophical paradigm that captures the whole of physical reality 'justified' in the name of science through an "unlimited [and unwarranted] extrapolation of this [mechanical] science to all

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[185] Isaac Newton, *Newton: Philosophical Writings*, ed. Andrew Janiak (New York: Cambridge University Press, 2004), 116.

[186] Newton, *Newton: Philosophical Writings*, 116. Emphasis added. Also: "Therefore if any man should say that bodies attract one another... **by a power seated in a substance**...**I know not why he should be said to introduce miracles and occult qualities and fictions into the world**. For Mr. Leibniz himself **will scarce say that thinking is mechanical as it must be if to explain it otherwise be to make a miracle, an occult quality, and a fiction." -** Newton, Newton: *Philosophical Writings*, 116. Emphasis added.

possible...phenomena."[187] For example, "it did not take long for Newton's strictures on how his *Principia* was to be interpreted to be forgotten, and for all his forces to be equated with physical causes in the strongest possible sense"[188] by, for instance, Immanuel Kant in his *Metaphysical Foundations of Natural Science (1786)* in which Kant reduces all causation mechanically to the efficient causes of fundamental forces,[189] despite Newton's claim that forces like gravity may be rooted in even deeper realities such as "a power whose cause is unknown to us, or by a power seated in the frame of nature by the will of God, or by a power seated in a substance."[190] Notable early modern scientists after Newton like Pierre-Simon Laplace too declared, contrary to Newton, that "the entire universe consisted of nothing but bodies undergoing motions through space ... that obeyed Newton's laws."[191]

It would take another two to three hundred years until the mid-twentieth century for the continued progress of science and philosophical reflection to gradually shake the reigning status of mechanical atomism and to spark interest amongst academics like Werner Heisenberg, Albert Einstein, David Bohm, Nancy Cartwright, Brian Ellis, Rom Harré, Brian Ellis, Alexander Bird, etc., to seek alternative metaphysics such as neo-Aristotelian-Thomism. We shall turn now, therefore, to the scientific discoveries that have gradually led to this paradigm change.

Section IV. Challenges to Mechanical Atomism From Classical Physics and Quantum Physics.

IV.1. The Wave Theory of Light. The wave theory of light provides one of the earliest indicators from classical physics that the atomistic-mechanistic picture of the world as comprised

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[187] Bohm, *Causality and Chance In Modern Physics*, p.37.

[188] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 256.

[189] "All natural philosophy consists rather in the reduction of given forces in appearance diverse to a small number of forces and powers...but which reduction only extends to fundamental forces, beyond which our reason cannot proceed."- Immanuel Kant, *Kant's Prolegomena: And Metaphysical Foundations of Natural Science*, trans. Ernest Belfort Bax (London: George Bell, 1883), 213.

[190] Newton, Newton: *Philosophical Writings*, 116.

[191] Bohm, *Causality and Chance In Modern Physics*, p.36.

of only microphysical bodies is not quite accurate. As shown by the famous double slit experiment of Thomas Young (1773-1829), light sometimes behaves in ways that are like water waves rather than particles. Consider the following illustration of the double slit experiment from Bohm (1957)[192]:

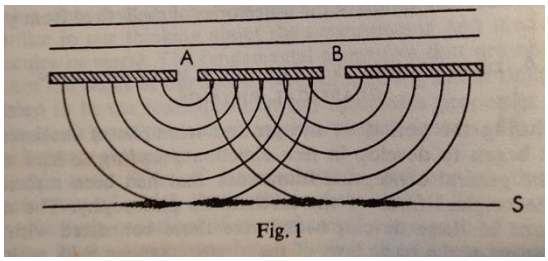

Fig. 1

Here, the beam of light from the top of the figure, shown as a set of wave fronts, travels through two slits A and B and reaches a screen S. Now, if light was comprised of small corpuscles, it should travel through the slits via straight lines and consequently only illuminate the parts of the screen that are directly "below" the two slits. In reality, however, the light not only illuminates the parts of the screen that are directly below the slits, but also those around it. What is more, what we see on the screen is not just two beams of light; rather, we see an interference pattern, that is, a set of "bright and dark fringes fairly close together,"[193] and these fringes are being represented in this figure with the thicker and thinner parts on S. Yet, if one of the slits is closed, the "fringes" or interference pattern disappears. These behaviors of light are very difficult to make sense of if light is comprised of small particles.

If light is understood as a wave, then the behaviors make good sense. For example, if light is like a water wave, this would explain why it not only illuminates the parts of the screen directly below the two slits but also the areas around them, and this is because like water waves, when light travels through an obstacle, opening point, or aperture, it will 'bend' and

[192] Bohm, *Causality and Chance In Modern Physics*, 40.
[193] Bohm, *Causality and Chance In Modern Physics*, 41.

consequently change from its original course of travel, and this phenomenon is part of the phenomenon known as "diffraction."[194] As for the interference pattern, it can also be understood as the interactions between the two waves of light coming from both slits, and where they cancel each other out, we see dark fringes on the screen, and where they add up, we see bright fringes on the screen.[195] The fringes forming the interference pattern disappears, however, if one of the slits is closed because now we no longer have two interfering light waves. Thus. the wave theory of light suggests that not all material things are like point-particles in space as imaged by mechanical atomism; rather, some of them, like water and light waves, can be distributed over space, and this notion that certain entities can 'spread out over space' in turn contributed to another development of classical physics away from mechanical atomism: field theory.

IV.2. Field Theory

We probably have all played with magnets and found them curious. The ancients were no different. The pre-Socratic philosopher Thales, for example, produced the first documented observation of electricity and magnetism in ancient Greece by recording that amber can become magnetic when rubbed against fur.[196] Aristotle too had observed the ability of torpedo fish (electric rays) to shock other fish with electricity and consequently causing a "torpor"[197] in them. In fact, the word *magnet* itself comes from the Greek *magnetis lithos*, which means the stone (*lithos*) coming from an area of Greece called Magnesia. Our English word *electricity* too comes from the Greek word for amber that is rendered *electrum* in Latin. Fast forward to the Medieval period, St. Augustine too noticed "properties of electricity (amber) and magnetism (lodestone)"

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[194] Bohm, *Causality and Chance In Modern Physics*, 41.
[195] Bohm, *Causality and Chance In Modern Physics*, 41.
[196] Anthony Rizzi, *Physics for Realists: Electricity and Magnetism. Modern Physics with a Common Sense Grounding* (*Baton Rouge, LA: IAP Press,* 2011), 9-10.
[197] Rizzi, *Physics for Realists: Electricity and Magnetism*, 9.

when he saw a fellow bishop "moving iron around through a silver plate."[198] The first scientific study of magnetism, however, was produced by the French physicist Peter the Pilgrim of Maricourt from the 13th century along with others such as John of St. Amand, Alexander Neckam, etc. The medieval studies on magnetism were summed up by William Gilbert (1544-1603) from Cambridge, who "credits St. Thomas Aquinas with noting iron is changed by a magnet."[199]

Fast forward again to our contemporary times, electricity and magnetism, thanks to the contributions of great minds like Michael Faraday, André-Marie Ampère, and James Clerk Maxwell, etc, are now understood as "fields." For example, Rizzi (2010) explains electric field this way: a charged body (which can be positively or negatively charged), can generate a power (quality) within the space around it in which the charged body can attract other bodies with the opposite charge, or repulse other bodies with the same charge. This property of space around a positively or negatively charged body is called its electric field.[200] Likewise, magnetic fields are present in the space around charged bodies that are moving (such as an electric current comprised of a stream of charged particles moving through a wire), and within this space, a power (quality) exists such that ferromagnetic materials will be attracted to the charged bodies in motion, which now also has a north pole and a south pole, and they will in turn attract the opposite poles and repulse the same poles of other charged moving bodies with magnetic fields.[201]

As such, electromagnetic fields are "*continuously distributed throughout space*,"[202] which shows the inadequacy or the incompleteness of the atomistic-mechanistic and even the

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[198] Rizzi, *Physics for Realists: Electricity and Magnetism*, 8.
[199] Rizzi, *Physics for Realists: Electricity and Magnetism*, 8.
[200] Rizzi, *Physics for Realists: Electricity and Magnetism*, 20.
[201] Rizzi, *Physics for Realists: Electricity and Magnetism*, 102.
[202] Bohm, *Causality and Chance In Modern Physics*, 42.

Newtonian understanding of matter as always comprised of small bodies in definite points. Consequently, the exact nature of these fields was a question that puzzled great scientists. For instance, Faraday and Maxwell thought that all space is full of a substance and medium called 'ether,' and that electromagnetic fields and gravity might be the manifestations of the "internal stresses"[203] of ether. Yet, no experimental proof of the existence of ether was ever discovered, and scientists eventually came to accept the existence of fields as "qualitative new kinds of existence"[204] apart from the issue of ether. Fields, therefore, are now accepted by scientists like Einstein as a new kind of existence that broaden our preciously atomistic notion of matter, which marks "an important step away from mechanism."[205]

IV.3. Molecular Theory of Heat, Kinetic Theory of Gases, and Wholeness.

Molecular theory of heat and kinetic theory of gases together formed a new branch of classical physics when it was developed in the mid 19th century by great scientists like Julius von Mayer (1814-1878) and James Prescott Joule (1818-1889), who observed that water became hot when it was in a turbulent and chaotic state caused by the continuous motion of a paddle-wheel.[206] This observation led to the assertion that heat was a kind of "chaotic"[207] motion of water molecules caused by the energy transferred to the water from the work of the paddle-wheel and its mechanical energy that created vortices in the water. In other words, mechanical energy and heat are convertible, because heat is the manifestation of chaotic and intense molecular motion that can be induced by the transfer of mechanical energy. This discovery further gave rise to a theory that gases also consisted of molecules in intense chaotic motion (like the water molecules), and since the heat energy of such kinetic gases are convertible with mechanical

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[203] Bohm, *Causality and Chance In Modern Physics*, 43.
[204] Bohm, *Causality and Chance In Modern Physics*, 44.
[205] Bohm, *Causality and Chance In Modern Physics*, 45.
[206] Bohm, *Causality and Chance In Modern Physics*, 47.
[207] Bohm, *Causality and Chance In Modern Physics*, 47.

energy, the creation of steam engines was thus made possible.

What is more, Bohm points out that the kinetic theory of gases exhibits a special significance as "the first example within physics of a qualitatively new aspect of the laws of nature ... that the *large-scale* over all statistical regularities can appear at the *macroscopic level* which are largely *independent of* the precise details of the ... motions ... at the *atomic level*."[208] The kinetic theory of gases thus marks a significant moment in which the continued development of classical physics has eventually resulted in an empirically based challenge against the core micro-physicalist assumption of mechanical atomism; that is, the kinetic theory of gases suggests that some macroscopic phenomena exhibit a certain degree of independence and autonomy. For instance, consider Bohm's example of a box of gas consisting of 10 to the 23rd power of molecules (that is, 100,000,000,000,000,000,000,000 molecules) with these molecules constantly colliding with each other and moving on highly irregular paths. What should we do if we wish to know some of the properties of this body of gas? From the microscopic perspective of mechanical atomism, it would seem appropriate to start with the individual particles and work 'bottom-up': if one could measure, for example, the velocity and position of each molecule and combine this information, eventually we will be able to know the properties of the gas body as a whole. Yet, Bohm argues that within the actual practice of science, this 'bottom-up' approach is "hopeless"[209] because it is an enormous and practically impossible task to measure each of these many molecules, let alone to overcome the immense mathematical difficulty related with calculating their position, velocity, angle of motion, and so on.

Thus, if we hope to know anything about this body of gas, we would have to change our approach and start from the 'top' and try to understand it as a whole. For example, we can

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[208] Bohm, *Causality and Chance In Modern Physics*, 49.
[209] Bohm, *Causality and Chance In Modern Physics*, 49.

investigate the "macroscopic average properties"[210] of this body of gas, such as its "mean density ... mean kinetic energy ... *which can be defined directly at the large-scale level*"[211] without the need for knowing the precise motions and arrangements of its many individual molecules. This is because these macroscopic properties are often quite insensitive to the conditions of the individual molecules since, as statistical mechanics have shown, the irregular motion of many molecules in situations similar to this example will mostly cancel each other out and result in a stable long term average value.[212]

The kinetic theory of gases thus provides evidence and justification for distinguishing the macroscopic whole from the microscopic parts at least for those macroscopic entities that seem to possess "a set of *relatively autonomous qualities ... relations ...* [and] *causal laws*."[213] Seen in this light, many macroscopic entities turn out to be more than the aggregate of their microscopic parts. For instance, water must be understood as a macroscopic entity because many of its characteristic features, such as being liquid, wetness, flow, local density, local stream velocity, pressure, temperature, etc., are expressed via "large scale properties alone."[214] One thus cannot treat water as a mere collection of water molecules if one wish to understand these curious features of water that cannot be quite put into microscopic terms. The macroscopic features, however, are by no means disconnected from the microscopic features. For example, the characteristic stability of a water body is at least in part due to the intermolecular forces that keeps the density of the water body at a stable level (it does so by repelling the water molecules from each other when they come too close, and attracting the molecules to come closer together when they become too distant), which allows the water body to remain stable as a macroscopic

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[210] Bohm, *Causality and Chance In Modern Physics*, 50.
[211] Bohm, *Causality and Chance In Modern Physics*, 50.
[212] Bohm, *Causality and Chance In Modern Physics*, 50.
[213] Such as those of thermodynamics and macroscopic physics in general. See Bohm, *Causality and Chance In Modern Physics*, 50.
[214] Bohm, *Causality and Chance In Modern Physics*, 50-51.

whole despite the motions of its individual water molecules or outside disturbances.[215]

This recognition of the physical world as distinguishable into at least two 'levels', namely, the macroscopic and the microscopic, marks a fundamental turning-away from the atomistic-mechanical assumption that the whole of physical reality is reducible to a set of microphysical and quantifiable parts. Instead, Bohm illustrates that the development of physics gradually brings the recognition that there exists wholeness in the macroscopic world that is not so easily reduced to microscopic parts, and wholeness enables us to further recognize a number of different "levels"[216] in the physical universe, such as the elementary, the atomic, the molecular, the biological, etc., each characterized by the holistic entities and their characteristic qualities, laws, etc., proper to their level.

IV.4. Einstein, Relativity, and Wholeness.

The recognition of **wholeness** in physics arguably reached its first climax with Einstein and the theory of relativity, which, for Bohm, is "one of the first real breaks"[217] with the general worldview of classical physics, and all this begun with a question Einstein asked himself when he was 15 years old: what happens if one looks at a mirror when moving at the speed of light (in a vacuum)?[218] Well, one would in fact see nothing at all for two reasons: firstly, even if we assume one could move at light speed, this would mean that the light being reflected by one's body surface would never have a chance to reach the mirror because it would have moved on (with light speed) before it does so. Secondly, one could in fact never maintain light speed in the first place because at light speed, "the electromagnetic fields that hold our atoms together would

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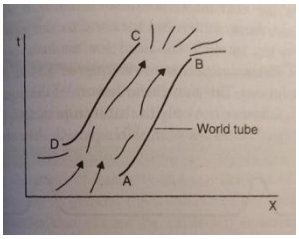
[215] Bohm, *Causality and Chance In Modern Physics*, 51.
[216] Bohm, *Causality and Chance In Modern Physics*, 51.
[217] Bohm, *Wholeness and the Implicate Order*, 17.
[218] Bohm, *Wholeness and the Implicate Order*, 155.

be left behind us ... As a result, our atoms would disperse, and we would fall apart."[219] One implication of Einstein's relativistic physics is therefore that the central atomistic-mechanical notion of an absolute atom or fundamental particle that everything is supposed to be composed of, becomes no longer possible to maintain, since to do so would mean to assume the existence of certain rigid bodies (the fundamental particles) that can in principle catch up with any finite speed.[220] Yet, this is not the case because light speed, though finite (299,792,458 meters per second in a vacuum), turns out to be an absolute and unreachable horizon relative to matter.

In order to accommodate the radically new features of Einstein's relativity, physics moved away from the mechanical atomism-based early modern model that sees particles as fundamental entities; instead, "*events and processes*" come to the front; for example, any localized realities that we are accustomed to regard as separate objects that exist "autonomously and permanently," such as particles, are now regarded by relativistic physics as abstractions within complex continuous processes that were described by Einstein as "world tube[s]:"[221]



Let this world tube represent a given localized structure S, or a 'sunflower' for convenience. Seeing from the light of this world-tube perspective, although we are accustomed to regard a sunflower as an absolute and autonomous entity, it is really a crude abstraction based on a particular point within a series of complex processes in flowing movement (such as the entire life cycle of the sunflower and even the grouping of certain minerals and biological materials before

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[219] Bohm, *Wholeness and the Implicate Order*, 155.
[220] Bohm, *Wholeness and the Implicate Order*, 155.
[221] Bohm, *Wholeness and the Implicate Order*, 157.

that, etc.), and these processes are represented by the arrows inside of the world tube figure. Each world-tube begins with certain conditions within its broader background (represented by lines A and D) and eventually collapse back into the background (represented by the lines following BC).[222] What is significant about a world tube is that it cannot be seen as composed of micro-parts in the atomistic-mechanistic sense, because these micro-parts will themselves also turn out to be abstractions within broader flowing processes that are describable as tubes, "*ad infinitum*."[223]

Einstein famously attempted to describe the entire universe as such a world tube in the form of a "unified field theory,"[224] in which localized objects like 'particles' are only abstractions for parts of this field with intense energy levels called singularities. Within this new worldview, the atomistic-mechanical idea of the world as divisible into separable small bodies became inadequate or irrelevant; "Rather, we have to regard the universe as *an undivided and unbroken whole* ... the order of undivided wholeness.[225]As such, Einstein went on in his attempt to articulate a consistent description of this unified field theory, and developed ground breaking notions such as curvilinear order and measure, etc. One such significant development, for the purposes of the present project, was Einstein's use of **"non-linear equations,"** which are equations "whose solution[s] cannot simply be added together to yield new solutions."[226] Consider Einstein's universal field. From an atomistic-mechanistic perspective, there is nothing wrong with the idea that we can regard it as the sum total or linear combination of all the "normal modes of motion of the entire field,"[227] since mechanical atomism regards the whole as only the sum of its parts. However, Bohm points out that Einstein's equations for the unified

[222] Bohm, *Wholeness and the Implicate Order*, 157.
[223] Bohm, *Wholeness and the Implicate Order*, 157.
[224] Bohm, *Wholeness and the Implicate Order*, 157.
[225] Bohm, *Wholeness and the Implicate Order*, 158. Emphasis added.
[226] Bohm, *Wholeness and the Implicate Order*, 158.
[227] Bohm, *Wholeness and the Implicate Order*, 159.

field theory are generally non-linear because they do not converge mathematically, which indicates that the whole is not simply always the sum of its parts, making "irrelevant"[228] the atomistic-mechanistic notion that the whole can always be analyzed by dividing it to its spatially separate microphysical parts in the non-linear context.

Einstein's project, however, was not able to reach a coherent and consistent state within his lifetime. Yet, Einstein's insights were nevertheless significant because, following the direction of the aforementioned developments in physics (the wave theory of light, field theory, molecular theory of heat and kinetic theory of gases), relativistic physics further pushes physics and our ontological imagination of the universe away from the atomistic-mechanical picture by emphasizing ever more clearly the notion of wholeness that was once prominent in pre-modern philosophy of nature (such as Aristotle's and Aquinas's 'forms'. More on this below in **Sections V and VI**), yet has since been obscured by the corpuscularian worldview of mechanical atomism. This outcry for acknowledging wholeness, however, intensifies even more with the quantum revolution.

IV.5. Quantum Physics, Bohm, and Wholeness.

IV.5.1 Main Features of the Quantum Theory (Part 1). According to Bohm, the quantum theory "overturned"[229] mechanical atomism even more thoroughly than relativity, and this may be illustrated through a brief discussion of the main features of the quantum theory. Let's begin with: **1.** "All action [is] in the form of what is called discrete quanta,"[230] and **2.** "All matter and energy [are] found to have ... a dual nature, in the sense that they can behave either like a particle or like a field - or a wave - according to how they are treated by the experiment.[231]

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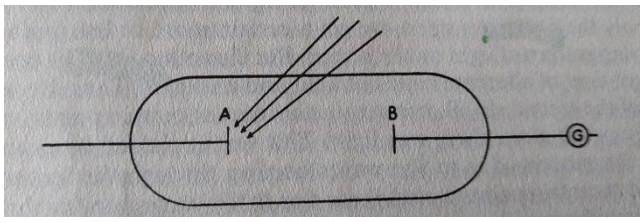
[228] Bohm, *Wholeness and the Implicate Order*, 160.
[229] Bohm, *Unfolding Meaning*, 6.
[230] Bohm, *Unfolding Meaning*, 6.Emphasis added.
[231] Bohm, *Unfolding Meaning*, 6.Emphasis added.

To begin, one of the first crucial indications of a 'quantum turn' in physics was revealed by the works of Planck and Einstein,[232] who discovered that energy can be imparted to matter by light in the form of 'quanta (quantum for singular)' or bundles of energy (later called 'photons') and the quantity of which can be calculated according to Planck's equation $E=hv$, where h represents Planck's constant and v represents the frequency of the light. An interesting fact about quanta is that they are 'discrete', that is, they are of definite values or quantities that cannot be broken apart. Consider the following illustration by Bohm of the photoelectric effect experiment[233]:



Within this experiment, light is shining upon a metal surface (A) that contains many electrons. Once the electrons receive enough energy from the light, they will be liberated from A and collected by another metal surface B. Now, according to classical physics, matter moves "continuously" (such that an object cannot move from one point to another without traveling through all the points between them) and that matter exchanges energy with electromagnetic waves like light "continuously"[234] (such that matter receives or loses energy in a continuous and cumulative fashion at rates proportionate to the intensity of the energy source). Yet, the photoelectric effect experiment revealed, contrary to the classical theory, that the electrons from A will always receive the same quantity of energy ($E=hv$) from the light proportionate to only

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[232] David Bohm, *Quantum Theory* (Garden City, New York: Dover Publication, 1989).

[233] Bohm, *Causality and Chance In Modern Physics*,71. See also Anthony Rizzi, *Physics for Realists: Quantum Mechanics. Modern Physics with a Common Sense Grounding* (*Baton Rouge, LA: IAP Press*, 2018), 14.

[234] Bohm, *Causality and Chance In Modern Physics*, 70.

the light's frequency v[235], regardless of the varying intensity of the light. In other words, the electrons receive the same amount of energy regardless of whether the light is strong or dim, and one straightforward interpretation of the photoelectric effect experiment is perhaps that light consists of indivisible light particles with energy value $E=hv$, which is transferred to matter, upon contact, in such definite values discretely.

Yet, it would be nice if the quantum realm can be this straightforward: for as Thomas Young and later physicists like Sergey Vavilov[236] have demonstrated, that light also behaves like a wave. Consider the double slit experiment again, but this time only one single quantum is allowed to pass a slit A at a time with both slits A and B open. Surely, the single particles of light will not be affected by the second slit B but will behave like particles and only pass through slit A? Alas, the experiment shows that after many quanta have passed through one slit one at the time, one will still obtain an interference pattern with bright and dark fringes, and Bohm suggests that this means "the opening of a second slit can prevent a *separate* and *independent* quantum from reaching certain dark points in the pattern which it could reach if that slit were closed. Hence, *even an individual quantum shows some wave-like properties*,"[237] as illustrated by Rizzi (2018):[238]

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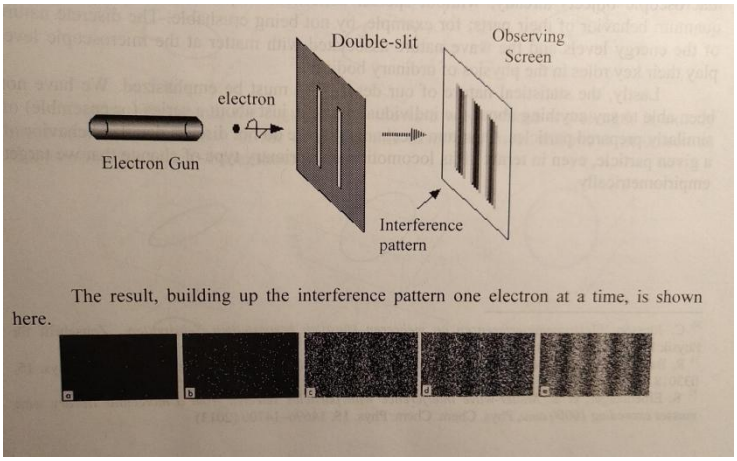
[235] Bohm, *Causality and Chance In Modern Physics*, 71.
[236] Bohm, *Causality and Chance In Modern Physics*, 72.
[237] Bohm, *Causality and Chance In Modern Physics*,73.
[238] Rizzi, *Physics for Realists: Quantum Mechanics*, 31.



Is light particle or wave, then? Or perhaps it is both?

Niels Bohr (1885-1962) was responsible for Quantum theory's next stage of development. Bohr wondered how can atoms be stable[239], since according to the classical theory, the electrons orbiting a nucleus should continuously lose energy as they radiate electromagnetic waves and eventually reach the nucleus, causing the atom to collapse. In reality, however, the electrons will reach a specific orbit according to the kind of atoms that they are part of, and stop radiating and remain in that orbit until it is otherwise disturbed.[240] This fact led Bohr to conclude that contrary to the classical theory, there are not a number of continuous possible orbits around a nucleus available for the electrons; rather, "the electron could follow only certain discrete ... orbits," amongst which there is a lowest possible orbit, and as soon as the electron enters this orbit, it stops losing energy and remains there indefinitely because "no more orbits of lower energy would be available for it to go to."[241]

The discrete nature of atomic energy orbit was further elaborated upon by Louis de Broglie (1892-1987), who suggested that like light particle/wave, atomic particles like electrons

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[239] Bohm, *Causality and Chance In Modern Physics*, 73.
[240] Bohm, *Causality and Chance In Modern Physics*,73.
[241] Bohm, *Causality and Chance In Modern Physics*, 74-75. Also: Bohm, *Quantum Theory*, 48-58.

also exhibit a wave-like nature[242] such that when they are situated in atoms, they will have certain definite "[discrete] frequencies of oscillation," (just like how a sound wave will resonate at discrete frequencies in a box, like that of a guitar, depending on the properties of the box) which in turn explain the "*discrete energies*"[243] levels of atomic particles according to Planck's equation $E = hv$. De Broglie's proposal later received experimental confirmation from the Davisson-Germer experiment[244] (1923-27), which confirmed that when scattered by metallic crystals, electrons displayed a diffraction pattern similar to the interference pattern of double slit experiment, which shows that electrons indeed have a wave-like character, and later experiments have confirmed the same for other particles including protons, molecules, and neutrons.[245]

These discoveries of quantum physics are ontologically significant because they contradict mechanical atomism in important ways: for instance, contrary to the atomistic picture that the world is divisible into many small bodies that travel continuously in space, quantum physics shows that all physical actions can be seen as the "connection of energy in the form of quanta,"[246] and since these quanta are discrete and indivisible and can jump from one energy orbit to another "without passing in between," the entire universe can thus be seen as an indivisible whole, having been woven together by "an interconnecting network of quanta"[247] that can travel from one place to another discretely. Furthermore, the fact that all matter can display either particle or wave-like character according to different experimental setups also suggest that, as Bohr famously argued, that the experimental environment, including the measuring apparatus, the observer, and the observed object, must be regarded as a "*single indivisible system...*united by

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[242] Rizzi, *Physics for Realists: Quantum Mechanics*, 30.
[243] Bohm, *Causality and Chance In Modern Physics*, 76.
[244] Rizzi, *Physics for Realists: Quantum Mechanics*, 29.
[245] Bohm, *Causality and Chance In Modern Physics* 77.
[246] Bohm, *Unfolding Meaning*, 6.
[247] Bohm, *Unfolding Meaning*, 6.

an indivisible quantum which connects them during the process of interaction."[248] For example, recall in the double slit experiment that even single particles will behave like particles without giving rise to an interference pattern when one slit is open and the other closed; yet, when both slits are open, the 'particles' will behave like waves and obtain an interference pattern. In situations like this, the atomistic-mechanical picture that the whole can always be understood by analyzing its separate parts "has no fundamental status"[249] since wave-particle duality only manifests when the observed particles as well as the experimental apparatus form a unified wholeness. Another note-worthy feature of quantum particles/waves is that they are much more reminiscent of organisms,[250] rather than lifeless machine parts, because they are capable of reacting to their environment in surprising ways. The atomistic-mechanical conception of the physical universe, therefore, appears more and more inadequate in light of the increasingly radical discoveries of quantum physics; and here, we shall examine two more such features:

IV.5.2 Main Features of the Quantum Theory (Part 2).

3. "Non-Locality of connection," and 4. "the state of the whole may actually organize the parts."[251]

One of the most curious and widely known phenomena of the quantum realm is no doubt quantum entanglement. Quantum entanglement was famously discussed in 1935 by Einstein, Podolsky, and Rosen (EPR) as a thought experiment[252] (aka the EPR experiment): suppose there are two entangled particles that are extremely far apart from each other. Due to their entanglement state, if we measure the momentum or position of one particle, this measurement

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[248] See Bohm, *Causality and Chance In Modern Physics*, 89, and Niels Bohr, Physical Review., 48, 696 (1935) as noted by Bohm.

[249] Bohm, *Wholeness and the Implicate Order*, 221.

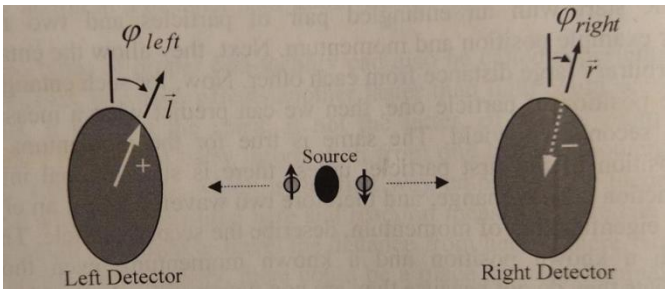
[250] Bohm, *Unfolding Meaning*, 6.

[251] Bohm, *Unfolding Meaning*, 7.

[252] Albert Einstein, Boris Podolsky, and Nathan Rosen, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review* 47, no. 10 (1935): 777-780.

will allow us to predict the momentum or position of the other particle as well.[253] Yet, this fact seems to violate the common sense of locality, the idea that physical things can only affect each other in close proximity, and one can already see this notion of locality in, for example, Descartes' definition of motion as a matter of small bodies being in local or "immediate contact"[254] with each other. Yet, quantum entanglement seems to suggest that entangled objects can somehow affect each other across great distance in a non-local fashion at speeds exceeding that of light, which greatly scandalized Einstein, who famously described entanglement as "spooky actions at a distance."

John Bell (1928-1990) contributed greatly to the clarification of the complex if not perplexing implications of EPR experiment by re-articulating the experiment with two "spin correlated particles": consider the following illustration of the Bell-EPR experiment by Rizzi (2018):[255]



In this experiment, a pair of entangled electrons are being emitted from a source toward opposite directions, and two detectors are placed on the left and right, respectively. The detectors are set at two different angles (φ_{left} & φ_{right}), so that, when an electron strikes a detector, the detector will yield a spin up (+) value if the electron's spin is oriented along the direction indicated by the solid black arrows; correspondingly, a detector will yield a spin down (-) value if the electron's

[253] Rizzi, *Physics for Realists: Quantum Mechanics*, 431.
[254] Descartes, *Principles of Philosophy*, p.32.
[255] Rizzi, *Physics for Realists: Quantum Mechanics*, 432.

spin is oriented opposite that arrow. Now, suppose we name the two electrons Alice (left) and Bob (right), respectively: what could be the probability distributions of their spin state(s)? Robert C. Koons (2019) argues that if one considers the two particles separately and applies classical Maxwell-Boltzmann statistics, then, there are four possible states each with a 25% probability:

1. Alice +1.Bob +1. **2.** Alice -1.Bob -1. **3.** Alice +1.Bob -1. **4.** Alice -1. Bob+1.[256]

In reality, however, the experimental result differs radically from this prediction: consider the following result of the Bell-EPR simulation from Rizzi (2018)[257]:

	LEFT DETECTOR											RIGHT DETECTOR										
L	1	2	3	4	5	6	7	8	9	10		1	2	3	4	5	6	7	8	9	10	**R**
0	+	-	+	-	+	-	+	-	+	-		-	+	-	+	-	+	-	+	-	+	**0**
60	-	+	-	-	+	-	+	-	+	-		+	-	+	+	-	+	-	+	-	+	**60**
120	-	+	-	-	+	-	-	+	-	+		+	-	+	+	-	+	+	-	+	-	**120**

This simulation illustrates that the spin states of the two entangled particles are correlated such that, according to the formula $\cos^2 (\phi_{left} - \phi_{right}) / 2$[258], they are anti-aligned (one measures + and the other -): 100% of the time when $\phi l = \phi r = 0°$, or $60°$, or 120°;

~75% of the time when $\phi l = 0°$ & $\phi r = 60°$;

~25% of the time when $\phi l = 0°$ & $\phi r = 120°$.[259]

What is significant about entangled systems like the ones represented above is that when two particles (electrons in this case) become entangled, they become one unified and emergent system that must be conceived as an undeniably non-separable whole[260] irreducible to its parts.[261] For example, if one conceives the two electrons as a unified system and applies Bose-Einstein statistics, which replaces the classical Maxwell-Boltzmann statistics, only three, rather than four,

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[256] Koons, "Thermal Substances," 5.
[257] Rizzi, *Physics for Realists: Quantum Mechanics*, 434.
[258] Where Cos =The cosine of an angle. See Rizzi, *Physics for Realists: Quantum Mechanics*, 435.
[259] Rizzi, *Physics for Realists: Quantum Mechanics*, 435.
[260] Koons, "Thermal Substances," 5.
[261] Robert C. Koons, "Multi-Scale Realism and Ontological Escalation: How the Quantum Revolution has Vindicated Aristotle," (2015): 17.

possible states each with a 1/3 probability are now recognized in an entangled two-particle system: “two [electrons] +1, two [electrons] -1, and one [electron] in each state.”[262] This means that the third and fourth probability distributions of the two electrons’ spin states given by Maxwell-Boltzmann statistics (3. Alice +1, Bob -1, and 4. Alice -1, Bob+1) now merge as one in quantum statistics[263] because quantum mechanics considers individual particles to have lost their distinguishable identities when they become part of a quantum system,[264] such as the entangled state in question. This entangled state now holds both electrons together in a holistic state of superposition[265] of all possible spin state(s) probability distributions, until one of them is actualized in the moment of measurement.

Rizzi too indicates that the entangled state of two particles must be described as a whole via the equation $1/\sqrt{2}\,(\,|\uparrow 1\rangle + |\downarrow 0\rangle\,)$[266], and “we cannot break up the ensemble that is described by this state into two pieces” because the entangled state has an “associated guiding structure that distinguishes it from that associated with the state [of the individual parts].”[267] Hence, entanglement is “a state in which two distinct entities must be considered together,”[268] or as a whole, which means, as Hüttemann (2004) argues, that it is no longer relevant, in this situation, to attribute “pure states to the parts of the compound. So the fact that the compound is in a determinate state cannot be explained in terms of determinate states the constituents occupy.[269] An entangled state, according to this interpretation, is not just the spin state of one particle plus the opposite spin state of another; rather, it is a distinct state that determines the spin states of its

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[262] Koons, "Thermal Substances,” 5.

[263] Michael Redhead and Paul Teller, "Particle Labels and the Theory of Indistinguishable Particles in Quantum Mechanics," *The British Journal for the Philosophy of Science* 43, no. 2 (1992): 204.

[264] Koons, "Thermal Substances,” 5.

[265] Andreas Hüttemann, *What's Wrong With Microphysicalism?* (New York: Routledge, 2004), 47.

[266] Rizzi, *Physics for Realists: Quantum Mechanics*, 446.

[267] Rizzi, *Physics for Realists: Quantum Mechanics*, 446.

[268] Rizzi, *Physics for Realists: Quantum Mechanics*, 446-447.

[269] Hüttemann, *What's Wrong With Microphysicalism?,* 47.

parts (the particles) from the perspective of the whole that one cannot create by combining its parts. Hence, Hüttemann (2004) argues that quantum entanglement presents a clear example of wholeness that cannot be reduced to the sum of its parts, which demonstrates, radically, "the failure of micro-explanation"[270]: the atomistic-mechanical thesis that the whole is always explainable via the aggregate of its parts.

This holistic implication of quantum entanglement is something that has been widely recognized. For instance, Ismael and Schaffer (2016) argue that the implication of the EPR experiment is non-separability, the idea that a composite system exhibits "further information (given in singlet [state])" that is not found in its individual part: a composite system is holistic and "more than the sum of its parts."[271] Maudlin also affirms that "the physical state of a complex whole cannot always be reduced to those of its parts, or ... their spatiotemporal relations..." since a composite system exhibits "an ineliminable holism,"[272] and these kind of claims, according to Kronz and Tiehen (2002), are strongly supported by the fact that "the time evolution of the density operator that is associated with a part of a composite system cannot in general be characterized in a way that is independent of the time evolution of the whole."[273] Quantum entanglement, thus, serves as an excellent demonstration for the last of Bohm's four points in his exposition of the radical features of quantum physics, that is, **"the state of the whole may actually organize the parts."[274]**

IV. 5.3. Toward a New Philosophy of Nature and Science: Wholeness and The Bohmian Causal/Ontological Interpretation of Quantum Physics.

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[270] Hüttemann, *What's Wrong With Microphysicalism?*, 47.

[271] Jenann Ismael, and Jonathan Schaffer. "Quantum Holism: Nonseparability as Common Ground." *Synthese* 197, (2020): (15) 4131-4160. https://www.jonathanschaffer.org/quantumholism.pdf.

[272] T Maudlin, "Part and Whole in Quantum Mechanics," in *Interpreting bodies: Classical and quantum objects in modern physics,* ed. E. Castellani (Princeton:Princeton University Press, 1998), 56.

[273] Frederick M Kronz, and Justin T. Tiehen, "Emergence and Quantum Mechanics," *Philosophy of Science* 69, no. 2 (2002): 343-344.

[274] Bohm, *Unfolding Meaning*, 7. Emphasis mine.

The proceeding exposition of the essential features of quantum physics serves to illustrate the striking gap between what science has progressively discovered since early modernity and the currently still popular atomistic-mechanical conception of the world based on early modern philosophy. For example, mechanical atomism conceives the world as divisible to quantifiable micro-bodies moving continuously in space, whereas quantum theory conceives the world as an indivisible whole connected by discrete quanta. Mechanical atomism conceives matter as localized micro-bodies with definite points in space, whereas quantum theory has discovered that all matter exhibits particle-wave duality and can be described as distributed throughout space. Mechanical atomism considers the microphysical "parts" to be primary and that the wholes are always reducible to the parts, whereas quantum theory suggests that there are irreducible wholes that can actually organize the parts with actual causal power.

As such, the atomistic-mechanical metaphysics is no longer an ontologically adequate worldview in light of the findings of contemporary science: to use Gerald Holton's schema, one may say that the **x and y axes** of science, namely, its empirical and mathematical aspects, have progressed way ahead of its **z-axis** or the (mechanical-atomist) **"thematic"**[275] aspect, which consists of our most fundamental presuppositions and philosophical convictions about reality. Yet, as noted by Bohm, the z-axis in Western academia still largely remains in the frame of early modern mechanical atomism, which has since been contradicted and transcended by both classical and quantum physics. It is high time, therefore, for the z-axis to catch up with the x and y axes if one, especially the philosophers, wishes to understand reality at an ontological depth through a metaphysics that is sufficiently informed by science.

Bohm makes precisely such a 'catch up' effort in the form of his 'Bohmian'

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[275] Wallace, *Causality and Scientific Explanation*, *Vol.II*, 241.

causal/ontological[276] interpretation of quantum mechanics. To begin, Bohm revises atomism by proposing that the so-called fundamental or elementary particle, such as an electron, is not some ultimately simple and structure-less entity; rather, it is in fact "highly complex"[277] and exhibits complicated inner structures that allow it to be affected, in very subtle ways, by a certain quantum field that is never separated from it.[278] This quantum field, which can be (at least partially) described via a wavefunction **ψ** according to Schrödinger's equation, acts as a "quantum potential *Q*"[279] that directs or guides the movement of the electron, just like how a classical potential *V* directs and guides the movement of a classical particle in classical mechanics as the forces that act on the particle.[280] The quantum potential *Q* is derived according to the following equation (related to the "de Broglie-Bohm(dBB) formalism,"[281]) from Bohm and Peat (1987)[282]:

$$Q = \frac{-h^2}{2m} \frac{\nabla^2|\psi|^2}{|\psi|^2}$$

In this equation, **ψ** represents the quantum field or wave function that is affecting a given particle, such as an electron, whose mass is given by *m*, and *h* presents Planck's constant.[283] The meaning of quantum potential *Q* is further clarified by Rizzi (2018), who argues that from the perceptive of dBB formalism,[284] the quantum potential *Q* represents "other causes"[285] (apart from the

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[276] Bohm and Hiley, *The Undivided Universe*.

[277] David Bohm and F. David Peat, *Science, Order, and Creativity* (London, New York: Bantam Books, 1987), 89.

[278] Bohm and Peat, *Science, Order, and Creativity*, 88.

[279] Bohm and Peat, *Science, Order, and Creativity*, 89.

[280] Bohm and Peat, *Science, Order, and Creativity*, 88.

[281] Rizzi, *Physics for Realists: Quantum Mechanics*, 69.

[282] Bohm and Peat, *Science, Order, and Creativity*, 89.

[283] Bohm and Peat, *Science, Order, and Creativity*, 89.

[284] Rizzi presents the **dBB formalism** as follows:

standard classical potential *V*) that are "act[ing] to give the "average" particle a certain impetus at a given place and time,"[286] and that the wave function (**ψ**), since it allows one to calculate *Q*, "contains information about the guidance of the particle (i.e. info about the guiding wave structure)."[287] This guiding wave structure, or "pilot wave" as it is often referred to, which is the "other causes," results indeed as *Q*, the quantum potential, when it affects the behaviors of particle(s). Thus, the **guiding structure,** which is either wholly or partially described by the **wave function ψ**, is the *cause* of the impetus (*effect*) of the guided particles, and the **quantum potential *Q*** describes the effect of the guiding structure upon the guided particles.

One revolutionary feature of the Bohmian guidance wave structure/quantum potential *Q,* is that it marks a fundamental break away, in our scientific picture of the physical universe, from the atomistic-mechanical treatment of causation, which only admits of efficient and material causes. Instead, the notion of quantum potential amounts to a radical retrieval of the Aristotelian-Thomistic notion of formal cause (more on this below in Section V and VI). Considered again the above equation for quantum potential *Q*:

> The fact that **ψ** is contained in both the numerator and the denominator for *Q* means that *Q* is unchanged when **ψ** is multiplied by an arbitrary constant. In other words, the quantum potential *Q* is independent of the strength, or intensity, of the quantum field but depends only on its ***form***...In the Newtonian world of pushes and pulls … any effect is

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$$\frac{d}{dt}\left(m\langle \mathrm{v}\rangle_x\right)=-\nabla\left(V+Q\right), \quad \text{with } Q=-\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}, \text{ and}$$

$$\frac{d}{dt}\equiv\frac{\partial}{\partial t}+\langle \mathrm{v}\rangle_x \nabla, \text{ which is the time rate of change with respect to a point moving with speed } \langle \mathrm{v}\rangle_x .$$

As Rizzi explains, the **dBB formalism**, which was first advanced by de Broglie and later again by Bohm (hence the name), can describe the evolution of a physical system, given its initial wave function conditions and a "certain physical setup characterized by a certain potential." See Rizzi, *Physics for Realists: Quantum Mechanics*, 69, 368.

[285] Rizzi, *Physics for Realists: Quantum Mechanics*, 69.
[286] Rizzi, *Physics for Realists: Quantum Mechanics*, 70.
[287] Rizzi, *Physics for Realists: Quantum Mechanics*, 70.

> always more or less proportional to the strength or size of the wave. But with quantum potential, the effect is the same for a very large or a very small wave and depends only on its overall shape.[288]

From a Bohmian perspective, the relationship between the quantum potential (cause) and the behaviour of the particles (effect) that it acts upon is thus not simply one of efficient causation in the typical atomistic-mechanical sense of an object A hitting another object B: in situations like this, the effect, such as the intensity of the object B's impetus resulting from being acted upon by A, is mainly determined by the intensity or strength (the category of *quantity*) of A's impetus and how much of this impetus can be transferred from A to B as kinetic energy. On the other hand, the quantum potential causes an effect, such as impetus, in the guided particles **not by 'hitting it' but by 'guiding' or 'giving form'** to the behaviour of the particles according to the quantum potential's own particular kind of form, which makes the effect of the quantum potential upon its guided objects dependent upon its form rather its intensity or strength. As such, the quantum potential is a very different type of cause (qualitative) than the mechanical cause (quantitative). In fact, Bohm describes the quantum potential not as a Newtonian object in motion but rather as a type of information, that is, an "**active information**"[289] defined as "a *form* having very little energy [that] enters into and directs a much greater energy. The activity of the latter is in this way given a *form* similar to that of the smaller energy."[290] Note that the notion of information Bohm utilizes here is quite literal, that is, information here refers to that which 'in-forms,' which is to "actively ... put form into something or to imbue something with form."[291] This notion of (active) information is further illustrated by Hiley and Bohm with the examples of

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[288] Bohm and Peat, *Science, Order, and Creativity*, 89-90.
[289] Bohm's notion of information will be discussed in more details in section VI below.
[290] Bohm, and Hiley, *The Undivided Universe*, 35.
[291] Bohm and Hiley, *The Undivided Universe*, 35.

radio and DNA.[292]

One particularly significant feature of the notion of **active information** is that it highlights and explains *wholeness* in nature as opposed to the atomistic-mechanical picture that all wholes are nothing but aggregates of their parts. For example, consider a two body system comprised of *two entangled particles*, which can be described via the following equation from Bohm and Hiley (1993)[293]:

$$\frac{\partial S}{\partial t} + \frac{(\nabla_1 S)^2}{2m} + \frac{(\nabla_2 S)^2}{2m} + V + Q = 0$$

From a Bohmian perspective,[294] this equation entails that the two entangled particles, mathematical operators for which are represented respectively by ∇_1 and ∇_2, are connected by the *quantum potential Q* even in the case that *V* is zero, where *V* represents the *classical potential* from the actions of (non-quantum) Newtonian forces. The quantum potential *Q* here is thus a common pool of energy that functions as a kind of active information by connecting, or informing the kinetic energies of the otherwise separated particles ∇_1 and ∇_2, such that if the kinetic energy of one particle changes, the other particle's energy simultaneously changes also, whilst the total kinetic energy of the two particles remains conserved. Evidently, an entangled system as such cannot be adequately analyzed into independent parts (i.e., as the sum of two separated particles) because the very entanglement of this system, as the above equation illustrates, must be explained holistically via the quantum potential *Q* as a common pool of energy that is an *active information* proper to the system as a whole.

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[292] Bohm and Hiley, *The Undivided Universe*, 35-36.

[293] Bohm and Hiley, *The Undivided Universe*, 36.

[294] I am deeply indebted here to Professor Basil J. Hiley, who kindly explained to me (via an email) the significance of this equation with respect to the notions of wholeness and quantum potential from a Bohmian perspective.

Another such example of wholeness that Bohm and Hiley (1993) discuss is a **hydrogen atom**, whose wave function can be written as "$\Psi = f(x)\, g(r)$", where x and r represent, respectively, the "center-of-mass" and "relative" coordinates of the atom.[295] The quantum potential *Q* of such a hydrogen atom, which contains an interaction term of its electron and proton, can be attained via the following equation:[296]

$$Q = -\frac{\hbar^2}{2\mu}\frac{\nabla^2 g(r)}{g(r)}$$

From a Bohmian perspective, the hydrogen atom is not simply the sum of its parts because the quantum potential **Q** as well as the wave function **r** (from which the **Q** is obtained)[297] of the hydrogen atom is not the result of the aggregation of a certain mode of interaction between its parts, such as the proton and the electron, and this is, in turn, due to the fact that no such definite mode of interaction exists between the parts in the first place! For instance, if the electron of the hydrogen atom is in the 1*s*-orbital, that is, its 'ground' state with the minimally possible energy level, the electron would in fact have an angular momentum of 0.[298] However, if it exists in a *p*-state, the electron has nonzero angular momentum.[299]

Now, the interaction between the electron and the proton is reflected in the wave function of the hydrogen atom, represented by its relative coordinate **r**; for example, the combined *s*+*p* wave function of the hydrogen atom depends on additional factors, such as the relative angle θ[300] that is the "angle between the angular momentum vector and the z-axis"[301] (where the z-axis, in

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[295] Bohm and Hiley, *The Undivided Universe*, 58.
[296] Bohm and Hiley, *The Undivided Universe*, 58.
[297] Bohm and Hiley, *The Undivided Universe,* 58.
[298] Samuel J. Ling, Jeff Sanny, and William Moebs, "The Hydrogen Atom," *University Physics Volume 3* (OpenStax, September 1, 2016). https://opentextbc.ca/universityphysicsv3openstax/chapter/the-hydrogen-atom/.
[299] Samuel J. Ling, Jeff Sanny, and William Moebs, "The Hydrogen Atom."
[300] Bohm and Hiley, *The Undivided Universe*, 58.
[301] Samuel J. Ling, Jeff Sanny, and William Moebs, "The Hydrogen Atom."

this case, refers to any direction along which "the experimenter decides to measure the angular momentum"[302]). Yet, an important question is: what exactly is **r**? Is it the wave function of the hydrogen atom with its electron in the s-state or the p-state, or any of its other quantum states such as the *d*, *f*, *g*, *h*, states? Yet, Bohm argues that to think along these lines is not fruitful because "it is impossible to find a single pre-assigned function of *r,* which would simultaneously represent the interaction of electron and proton in both *s*- and p- *states,*"[303] or any of the other quantum states, for that matter. A Bohmian approach, however, would highlight that the wave function **r** of the hydrogen atom reflects, to use Rizzi's term, the guidance structure that directs the hydrogen atom as a whole by acting as its quantum potential Q. The Q acts on the hydrogen atom holistically as a common pool of energy, like the Q of the above discussed entangled system, that 'binds' the parts of the hydrogen atom together such that these parts will interact according to the form of the hydrogen atom that is contained in **r**, which is, in Aristotelian-Thomistic terms, the **formal cause** of the hydrogen atom (more on this below in **Sections V and VI**). In Bohm's own words, the electron and the proton, as parts of the hydrogen atom, are determined, in their modes of interaction, by the "many-body wave function"[304] of the atom as a whole, since the many-body wave function (in this case the **r**, which acts as Q**)** "is said to determine the quantum state"[305] of physical systems like the hydrogen atom.

> In light of the preceding, Bohm and Hiley (1993) make a crucial observation:
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> The relationship between parts of a system described above implies a new quality of *wholeness* of the entire system going beyond anything that can be specified solely in terms of the actual spatial relationships of all the particles. This is indeed the feature

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[302] Samuel J. Ling, Jeff Sanny, and William Moebs, "The Hydrogen Atom."
[303] Bohm and Hiley, *The Undivided Universe*, 58.
[304] Bohm and Hiley, *The Undivided Universe*, 58.
[305] Bohm and Hiley, *The Undivided Universe*, 58.

> which makes the quantum theory go beyond mechanism of any kind. For it is the essence of mechanism to say that basic reality consists of the parts of a system which are in a preassigned interaction. The concept of the whole, then, has only a secondary significance, in the sense that it is only a way of looking at certain overall aspects of what is in reality the behaviour of the parts. In our interpretation of the quantum theory, we see that the interaction of parts is determined by something that cannot be described solely in terms of these parts and their preassigned interrelationships. Rather it depends on the many-body wave function ... Something with this kind of dynamical significance that refers directly to the whole system is thus playing a key role in the theory. We emphasise that *this is the most fundamentally new aspect* of the quantum theory.[306]

As Bohm explicates, therefore, that the quantum theory has dealt a heavy blow to mechanical atomism because, as Bohm and Hiley pointed out above, it is a fundamentally new aspect of the quantum theory that it reveals genuine wholeness in the universe. These 'wholes' and their common pools of active information[307] in turn must be acknowledged as being part of our fundamental ontology of the real because these 'wholes,' such as the " 'quantum state' of [*a*] *system as a whole*,"[308] can really affect their constituents with genuine causal efficiency and are thus capable of explaining, as real causal factors, phenomena that "cannot be described solely in terms of [their] parts and their preassigned interrelationships."[309] Wholeness thus distinguishes physical systems that are "*wholes* guided by a pool of common information [from] systems constituted of independent parts guided by *separate* pools of information."[310] The above

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[306] Bohm and Hiley, *The Undivided Universe*, 58-59. Emphasis mine.

[307] As mentioned above, Bohm's notions of information and 'common pools' of information will be discussed with more detail in section VI below. See also:Bohm and Hiley, *The Undivided Universe*, 60.

[308] D. G. Bohm and B. J. Hiley, "Intuitive Understanding of Nonlocality as Implied by Quantum Theory," *Foundations of Physics* 5, no. 1 (1975): (7)93-109. https://ui.adsabs.harvard.edu/abs/1975FoPh....5...93B/abstract.

[309] Bohm and Hiley, *The Undivided Universe*, 58.

[310] Bohm and Hiley, *The Undivided Universe*, 61. Emphasis mine.

discussed quantum systems of entanglement, double slit experiment, hydrogen atom as well as other phenomena such as hydrogen molecules and even macroscopic systems like the human body, superfluidity and superconductivity[311], etc, are, according to Bohm, all examples of systems guided by this type of holistic common pool of information, which ranges in type from wave functions to the biological information of living organisms.[312]

IV. 6. Summary, Conclusion, and Implication.

As such, our examination of some of the major scientific challenges that mechanical atomism faces in light of both classical and quantum physics has perhaps reached a preliminarily satisfactory point. What we can see is that far from the simplistic atomistic-mechanical picture that our contemporary society has inherited from early modernity, the continued discovery of science in fact presents us with a far more complex world filled with fascinating phenomena. The **wave theory of light** and the **field theory** already encouraged our imagination to step beyond the atomist schema and to conceive the world via the notion of waves. **Molecular theory of heat** and the **kinetic theory of gases** gave us the first glimpse of wholeness in a time when the 'thematica' of science was dominated by the concern for the quantifiable and the divisible. **Einstein** boldly challenged mechanical atomism further by conceiving the whole universe as a unified field in which all localized structures are its energy vortexes in process. **The quantum revolution** pushed us even further by revealing the **discrete quanta** and the **particle-wave duality** of all matter. Still more incredible is the **non-locality** of connection that is coupled with the amazing discovery of **wholeness** that functions as active in-formation of matter/energy. Mechanical atomism thus seems more and more inadequate as a metaphysics to guide our fundamental conceptions of the world. This issue will be even more sharply expressed by

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[311] Bohm and Hiley, *The Undivided Universe*, 65-71.
[312] Bohm and Hiley, *The Undivided Universe*, 71.

Quantum Field Theory, which, by illustrating that the so-called fundamental particles are all subject to creation, annihilation, decay, absorption, etc,[313] moves away from even the left-over atomist assumption in quantum mechanics, namely, the Democritean belief that the fundamental particles are indestructible.[314]

As such, following the call of David Bohm to re-examine our fundamental ontology in light of contemporary science, I propose that *the Bohmian causal/ontological interpretation of physics* points to and can be connected to two significant contemporary philosophical movements: *emergentism* and *the neo-Aristotelian revival*, in a mutually enriching and fulfilling fashion. Indeed, it is precisely the aim of this thesis to illustrate that: **(1)** the Bohmian causal/ontological interpretation provides concrete evidence for the claims of emergentism that there exist irreducibly emergent phenomena in nature; and **(2)** Such *emergent entities* can be robustly formulated via an Aristotelian-Thomistic philosophy (with its notion of formal causation) that can help us more adequately understand the cosmos as it is discovered by science in a holistic and non-reductionistic fashion. It is to these tasks that we shall now turn in the next session.

Section V: Emergentism, and Aristotelian-Thomism: an alternative metaphysics to mechanical atomism.

Section V.1.: The Nature and History of Emergentism.

Broadly conceived, Emergentism may be defined as the claim that there exist "a wide variety of phenomena – studied by numerous disciplines in natural and human sciences – where

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[313] Nigel Cundy, "Aristotelian *Potentia* and the Measurement Problem," *The Quantum Thomist* (blog), May 11, 2022, http://www.quantum-thomist.co.uk/my-cgi/blog.cgi?first=23&last=23.

[314] As the British Physicist Nigel Cundy notes: "The mechanical philosophy is dead, buried, mourned for, had its obituary published in the Times, dug up by archaeologists, and had its rotting remains displayed in the museum of ancient artefacts as a prime example of philosophical dead ends. Classical physics was its midwife; quantum physics its undertaker." - Nigel Cundy, "Aquinas' First Way and Modern Physics?" *The Quantum Thomist* (blog), May 11, 2022, http://www.quantum-thomist.co.uk/my-cgi/blog.cgi?first=39&last=39.

new processes, interactions, entities, and properties are claimed to be observed, characteristic for higher levels of complexity of matter and irreducible to their lower-level constituents."[315] As such, Tabaczek (2020) rightly argues that emergentism goes back at least to Aristotle,[316] who stated that: "For all things which have several parts, and of which *the whole is not a kind of heap but is something over and above the parts*, have some cause that makes them one."[317]

Emergence became a prominent subject in modern academic discussions in the late nineteenth and early twentieth-century Britain: during this time, thinkers such as John Stuart Mill, George Henry Lewes, and Charlie Dunbar Broad, etc., utilized the notion of emergence as a response to the atomistic-mechanistic metaphysics of the time, and this can be seen, for example, in the thoughts of C.D. Broad, who, as Humphreys (2016)[318] illustrates, defines the kind of reductionistic metaphysics that we have been calling 'mechanical atomism' 'pure mechanism.'[319] Like Bohm, Broad argues that pure mechanism is proven inadequate if there exist certain emergent 'wholes' with novel characteristics that cannot be deduced from or reduced to that of its constituents, and if such emergent entities exist, mechanical atomism would be undermined.[320]

Humphreys (2016)[321] points out that the concern for the 'whole' is an essential principle of modern theories of emergentism "since the earliest explicit investigations into emergence"[322] beginning as early as John Stuart Mill,[323] and especially George H. Lewes, who coined the term

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[315] Tabaczek, "Emergence," 1.
[316] Tabaczek, "Emergence," 2.
[317] Aristotle's Text in Book VIII, Lesson 5, Chapter 6: 1, 1045a, p.579 of Thomas Aquinas, *Commentary on Aristotle's Metaphysics*, trans. John P. Rowan (Notre Dame: Dumb Ox Books, 1995). Emphasis mine.
[318] Paul Humphreys, *Emergence: A Philosophical Account* (Oxford: Oxford University Press, 2016), 96.
[319] Charles Dunbar Broad, *The Mind and Its Place in Nature* (London: Kegan Paul, Trench, Trubner & CO., LTD, 1925), 45.
[320] Broad, *The Mind and Its Place in Nature*, 61.
[321] Humphreys, *Emergence: A Philosophical Account*, 94.
[322] Humphreys, *Emergence: A Philosophical Account*, 94.
[323] John Stuart Mill, *System of Logic*, *Ratiocinative and Inductive, Being a Connected View of the Principles of Evidence and the Methods of Scientific Investigation* (London: John W. Parker, West Strand, 1846).

"emergents."[324] A natural atomistic-mechanistic response to emergentism, however, is that the progress of science will eventually discover even more fundamental entities in nature to which the so-called emergent entities are reducible. Yet, emergentism turns out to be alive and well even in the twenty-first century because "increased scientific knowledge has not expelled emergence from the realm of well-understood science; instead, it has provided solid evidence that emergent phenomena lie within the various natural sciences."[325] As such, let's now turn to (1) an investigation of the key features of emergence according to contemporary theories followed by (2) a discussion of some possible examples of emergence.

Section V.2. : Key Features of Emergence.

(1) Qualitative Newness of Emergents. Many attempts have been made to capture the precise definition of emergence. Indeed, of the already vast growing body of literature on emergentism, one may say that they are only unified by their diversity.[326] Nevertheless, one central subject that every theory of emergence has to confront is the notion that the emergent entities, or the 'emergents', whether processes, properties, laws, or substances, etc., are not simply the result of a quantitative aggregation of some basal or prior realities; rather, emergent entities are qualitatively new realities with respect to their basal or prior realities. One classic example of this 'emergent newness' is J.S. Mill's notion of "heterogeneous effect," which refers to those products of combined chemical reactions that are "not an algebraic sum of the effects of each reactant."[327] As such, heterogeneous effects exhibit a qualitative newness that distinguishes them from "homopathic effect,"[328] which is simply the result of the quantitative sum or composition of its constituents. This kind of distinction between the 'heterogeneous' and the

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[324] George Henry Lewes, *Problems of Life and Mind*, (UK: Trubner and Co, 1875).

[325] Humphreys, *Emergence: A Philosophical Account*, 95.

[326] See, for example, Michele Paolini Paoletti and Francesco Orilia,*Philosophical and Scientific Perspectives on Downward Causation*, (New York: Routledge, 2017).

[327] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 47.

[328] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 46.

'homopathic' was further clarified by George Henry Lewes, who distinguished between effects that are emergent and effects that are merely resultant, with the former denoting effects that are "incommensurable and irreducible to the sum of their components."[329]

Furthermore, there cannot be a 'new' unless there is an 'old.' Indeed, the very characterization of emergents as qualitatively new phenomena imply that the emergents have a connection with respect to some "earlier or more basic entities" that the "emergent entities must result from."[330] Humphreys suggest that this relationship between the emergents and their basal conditions can be captured by the formula "X is emergent with respect to Y."[331] One obvious question, however, is: What exactly makes emergent entities (X) emergent, or qualitatively new in relation to their basal or prior realities (Y)? This brings us to the second and third features of emergence: novelty and autonomy.

(2) Novelty & (3) Autonomy. Novelty denotes something new. As Humphrey puts it: something **E** is "**novel** with respect to a domain **D** just in case **E** is not included in the closure of **D** under the closure criteria **C** that are appropriate for **D**."[332] The key word here is *closure*, and it might be preliminarily understood as 'that which can be disclosed or understood about a reality (**D**) by an appropriate criteria (**C**).' On this interpretation, a reality **E** would be novel to another reality **D** if and only if it is impossible for us to explain **E** with even our most complete knowledge of **D** yielded by its best **C**, such as the facts, principles, frameworks, etc., that are most appropriate for disclosing or understanding **D**.

This definition of novelty might first seem trivial, since it seems like almost everything can be described as novel because many things cannot be explained by other things; for example,

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[329] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 47.
[330] Humphreys, *Emergence: A Philosophical Account*, 27.
[331] Humphreys, *Emergence: A Philosophical Account*, 28.
[332] Humphreys, *Emergence: A Philosophical Account*, 29. Emphasis added.

physics would be novel to cheese since cheese cannot possibility write equations. As such, novel features seem way too common to be interesting. On the other hand, however, novelty is in fact very rare and significant if one considers the implication of mechanical atomism: on this metaphysics, all phenomena are simply the result of the quantitative aggregation of the fundamental particles, which entails that nothing is really novel, since the domain of fundamental particles **D** would in this case be able to fully explain everything according to its closure criteria **C**, that is, the quantitative aggregation of fundamental particles.

However, if there are some phenomena that one simply cannot explain via the quantitative aggregation method of mechanical atomism[333], these phenomena would then be truly novel with respect to the global domain of mechanical atomism and its closure criteria. Indeed, one may even say that the emergent entities have a kind of autonomy on their own above the atomistic-mechanical domain since at least some features of these emergent entities are not completely dependent on the features of their microphysical parts. In fact, the kind of quantum 'wholes' that Bohm discusses are prime examples of autonomous entities with novel features, such as an entangled system that can organize its constituents in a correlated matter with its holistic quantum state. This example naturally brings us to one last (but not least) feature of emergence:

(4) Holism. It is true that many things we see in the physical universe, as mechanical-atomism envisions, are like Legos in that they are composed of microphysical parts; but, is this the whole and exhaustive truth about our world, and ourselves? Holism is a loud "no" to this question because holism claims that not all phenomena are mere "aggregate phenomena"[334] that are nothing but Lego pieces put together; instead, holism claims that some 'wholes' have unique

[333] Humphreys, *Emergence: A Philosophical Account*, 29-32.
[334] Humphreys, *Emergence: A Philosophical Account*, 35.

properties proper to themselves that do not result from the aggregate of their parts. As such, these wholes are qualitatively new and emergent phenomena since they exhibit a kind of novelty and autonomy apart from the world of Lego or fundamental particles by virtue of their holistic properties.

Many accounts have been given in attempts to identify and articulate what these holistic properties are.[335] Here, we shall focus on one particular approach because of its applicability to the Bohmian causal/ontological interpretation of physics: top-down causation, or Downward Causation (DC). First introduced by Donald Thomas Campbell, DC is usually defined as: "the causation of lower-level effects by higher level entities ... [e.g.] a cell constrains what happens to its own constituents; a body regulates its own processes; two atoms, when they are appropriately related, make it the case that their own electrons are distributed in certain ways.[336]

It is a well known issue, however, that 'level' is hard to be defined accurately.[337] In our case, it might be helpful to preliminarily conceive 'level' as the relation between any phenomena to the domain of mechanical atomism in which all phenomena are on the same 'level' because they are, fundamentally, the same *kind* of reality: aggregates of fundamental particles. In this case, the 'bottom-up'[338] causation would be the only real mode of causation since all things are ultimately reducible to the activities of the fundamental particles. Yet, if there exist some phenomena that cannot be explained as resultant from the activities of the fundamental particles, these phenomena would be something novel and autonomous, and would thus stand on a higher 'level' in relation to the atomistic-mechanical domain as qualitatively new *kinds* of reality. DC is precisely such a claim that there exist phenomena that do not merely result from the same-level

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[335] See, for example, Tabaczek, *Divine Action and Emergence*, 34-46. Humphreys, *Emergence: A Philosophical Account*, 37-43, 94-141.144-193.

[336] Paoletti and Orilia, "Downward Causation," 1. Emphasis added.

[337] Paoletti and Orilia, "Downward Causation," 2-3.

[338] Paoletti and Orilia, "Downward Causation," 1.

interactions of the fundamental particles; rather, they are capable of acting upon the fundamental particles, as it were, from a domain 'above' them.

Holism is *one* case of such 'top-down' or downward causation. In this case, DC is typically defined as "dynamic causal relations between complex wholes and their constitutive parts."[339] Evidently, if there exist such 'wholes' that can exercise (downward) causal powers upon its microphysical constituents, these 'wholes' would then not be mere aggregates of their fundamental particles but something novel, autonomous, qualitative new, and, indeed, *emergent*[340], with respect to the domain of mechanical atomism.

Section V.3. : Emergence: Possible Examples. With these four key features of emergence (**(1)** qualitative Newness, **(2)** novelty, **(3)** autonomy, and **(4)** holism) in place, we shall now proceed to take a look at some possible examples of emergence. Historically, emergence has been used in a "bewildering variety of senses,"[341] including weak emergence, strong emergence, epistemological emergence, supervenience, inferential emergence, conceptual emergence, etc. However, we shall focus here on arguably the strongest form of emergence: ontological emergence. Ontological emergence asserts that "some emergent features or objects are real features of the world and their status as emergent ... [is their being] objective and autonomous components of the world, rather than artifacts of a representational apparatus or of our epistemological limitations."[342] Humphreys[343] and Robert C. Koons[344] argue that one representative type of ontological emergence is *fusion emergence*, which is defined by "the loss

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[339] Tabaczek, *Divine Action and Emergence*, 34.
[340] Tabaczek, *Divine Action and Emergence*, 34.
[341] Koons, "Multi-Scale Realism," 3.
[342] Humphreys, *Emergence: A Philosophical Account*, 56.
[343] Humphreys, *Emergence: A Philosophical Account*, 70.
[344] Robert C Koons, "Hylomorphic Escalation: An Aristotelian Interpretation of Quantum Thermodynamics and Chemistry," *American Catholic Philosophical Quarterly* 92, no.1 (2018): (8)159-178. https://www.pdcnet.org/acpq/content/acpq_2017_0999_12_4_139. Koons, "Multi-Scale Realism,"18.

of such basal objects or properties when they fuse to produce a unified whole."[345] More specifically, fusion emergence occurs when two (or more) objects of a domain **D**, such as A and B, interact, "result in both A and B being transformed in a radical manner, losing the essential property of existence, with the resulting entity being the fusion of the two," such that the resulting entity "is never a combinatorial rearrangement of existing entities,"[346] but "a fundamentals entity of the original domain or a member of some other domain."[347]

On this definition, the fused entity *E* would satisfy the *autonomy* and *holism* criteria by virtue of the loss of the original identities of the basal entities A and B during fusion. In addition, when E also exhibits novel features with respect to A and B, E would thus be something qualitatively new in relation to A and B and thus a case of ontological emergence. One frequently proposed candidate for ontological fusion emergence is, unsurprisingly, quantum entanglement.[348] Recall Bohm and Hiley's (1993) interpretation that entanglement between two particles (whose differential operators are those mentioned earlier, namely ∇_1 and ∇_2) results from the effect of a common pool of energy: the quantum potential Q[349], that, as active information, in-forms and directs the kinetic energies of the otherwise separated particles 1 and 2, such that if the kinetic energy of one particle changes, the other particle's energy changes simultaneously whilst the total kinetic energy of the two particles remains conserved, which results in, for example, the anti-correlation of their spin states. This Bohmian causal/ontological interpretation of entangled state vividly illustrates what Koons (2015) calls the "fusion of microscopic individuals"[350] in which particles appear to have "lost all individuality, having been

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[345] Humphreys, *Emergence: A Philosophical Account*, 72.
[346] Humphreys, *Emergence: A Philosophical Account*, 74.
[347] Humphreys, *Emergence: A Philosophical Account*, 72.
[348] Humphreys, *Emergence: A Philosophical Account*, 81.
[349] Bohm and Hiley, *The Undivided Universe*, 36.
[350] Koons, "Multi-Scale Realism," 18.

absorbed into an undivided unity with an internal structure."[351] For example, recall Koons's (2019) argument that the probability distributions of the two particles' spin states are no longer calculated by quantum or Bose-Einstein statistics on an individual bases; rather, the two particles are considered via one probability distribution: (Alice +1 Bob -1 & Alice -1 Bob+1)[352], which for Koons means that "there are no longer two distinct particles in the quantum fusion."[353] Kronz and Tiehen (2002) too argue that the component particles of an entangled system are linked by a "continual essential interaction," and such links may be "so robust that it is no longer meaningful to talk about components that are parts of a compound, meaning that there are components only with reference to what existed prior to the interaction and what exists after the interaction has ceased.[354]

As such, an entangled system is a plausible candidate for ontological emergence: by virtue of existing as a holistic compound that can direct and inform the movement of its components (if they even can still be meaningfully said to exist while in a fused state) via a characteristically 'downward' causation from the whole, the entangled system satisfies the *holism* condition for emergence. Moreover, the entangled whole exhibits truly novel features that cannot be deduced from the features of its components, and this can be illustrated straight forwardly from the key principle of relativity: recall Einstein's insight that no objects and signals can travel faster then the speed of light.[355] This would mean that entanglement cannot be understood reductionistically as the result of one particle somehow sending a signal to its entangled pair that informs its movement instantaneously because two entangled particles can exist far enough apart from each other to the extent that a signal would have to travel faster than

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[351] Koons, "Multi-Scale Realism," 18.
[352] Koons, "Thermal Substances," 5.
[353] Koons, "Multi-Scale Realism," 18.
[354] Frederick M.Kronz and Justin T. Tiehen, "Emergence and Quantum Mechanics," *Philosophy of Science* 69, no. 2 (2002): 340.
[355] Bohm, *Wholeness and the Implicate Order*, 155.

light in order to reach the other particle instantaneously.

Therefore, Bohm and Peat (1987) argue that the non-local connection between entangled particles is not due to signals emitted by the individual particles, but due to the quantum potential Q of the entire entangled system that "does not fall off with the distance between particles."[356] The Q is thus capable of guiding or giving "form"[357] to the movement of the particles in a correlated way across great distance non-locally. Therefore, if the entangled-ness of an entangled system is due to no features of its components but its holistic quantum potential Q, this entails that the entangled system exhibits a truly **novel** feature with respect to its component particles, which further entails that the entangled system has a degree of **autonomy** from the determination of its components and is something **qualitatively new** and not just an aggregate of its parts. Thus, an entangled system can be argued as satisfying all four conditions for emergence and is therefore an emergent entity with respect to its basal particles.

Another possible candidate for ontological fusion emergence is a **hydrogen molecule**.[358] Consider two hydrogen atoms, each composed of a proton and an electron: these four entities are easily distinguishable when the two atoms are spatially far apart. However, because electrons are indistinguishable particles, their "electron wave functions [will] overlap to such an extent that it is impossible to individuate them"[359] when the two atoms become proximate. Humphreys argues that in this case, one can no longer distinguish one electron from another; rather, the significant overlap of the electron wave functions suggest that they are now "a fused entity - a single "object" that is shared by two protons."[360] One further result of this fusion, or "covalent bond,"[361] between the outer electrons of the two atoms is that one can no longer identify the original

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[356] Bohm and Peat, *Science, Order, and Creativity*, 98.
[357] Bohm, and Hiley, *The Undivided Universe*, 35.
[358] Humphreys, *Emergence: A Philosophical Account*, 82.
[359] Humphreys, *Emergence: A Philosophical Account*, 83.
[360] Humphreys, *Emergence: A Philosophical Account*, 83.
[361] Humphreys, *Emergence: A Philosophical Account*, 83.

hydrogen atoms 1 and 2 in the fused state (if they were originally identified with their respective protons and individuated electrons before the bonding) because their individuated electrons no longer exist. Instead, one now has a hydrogen molecule that cannot be accurately described as "being composed of individual atoms bonded together," but rather as "a set of nucleons together with a charge density distribution."[362]

Comparing to the two hydrogen atoms, the "electron density of the outermost electrons spread out over the entire molecule, rather than being concentrated in the regions around individual atoms, decreases the overall energy [of the molecule] and enhances the stability of the molecule."[363] As such, a hydrogen molecule fulfills the **holism** criterion for emergence by virtue of its fused state in which there are no longer separated atoms. Moreover, the molecule exhibits **novel** features insofar as the fused electron density is spread out around the whole molecule and enhances its stability, which is a feature that cannot possibly be found in the individuated hydrogen atoms prior to the fused state. Hence, the molecule may be said to exhibit **autonomous** features proper to itself in a holistic state, which, together with its holism and novel features, make the hydrogen molecule something **qualitative new** and **emergent** with respect to its basal or prior entities that are the hydrogen atoms.

Interestingly, Bohm and Hiley (1993) also discuss a hydrogen molecule and its covalent bond as a case of quantum wholeness.[364]Again, Bohm offers an ontological interpretation of quantum physics that recognizes holism in a way that coincides with emergentism: for Bohm, a hydrogen molecule is irreducible to its constituents precisely because it is a 'whole' by virtue of its quantum potential Q that is proper to the molecule as a whole. This Q of the hydrogen

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[362] Humphreys, *Emergence: A Philosophical Account*, 83.
[363] Humphreys, *Emergence: A Philosophical Account*, 84.
[364] Bohm and Hiley, *The Undivided Universe*, 65. For the mathematical derivation of the hydrogen molecule's quantum potential and wave function, see Bohm and Hiley, *The Undivided Universe*, 63-64.

molecule, as a common pool of information, can direct or in-form the movement of its constituents, such as stabilizing the molecule by giving "rise to an attraction between the protons at medium distances, which turns into a repulsion at short distances."[365] As such, a hydrogen molecule, like the entangled quantum systems, are "wholes guided by a pool of common information,"[366] which explains their novel features as emergent wholes.

Section V.4. : Holism, Emergence, Bohm, and the Aristotelian-Thomistic Formal Causation.

From the above discussions of two possible examples of ontological fusion emergence as well as the highlighted connection between emergence and the Bohmian causal/ontological interpretation of quantum physics, two significant observations can be drawn:

Firstly, the Bohmian interpretation offers strong evidential support to emergentism. After all, if emergentism is going to offer a successful alternative ontology to mechanical atomism, emergentism must establish the truth of the following *modus tollens* argument:

1. If mechanical atomism is true (If P), then all phenomena in the physical universe can be exhaustively explained as aggregates of the most fundamental particles (then Q).
2. It is not the case that "all phenomena in the physical universe can be exhaustively explained as aggregates of the most fundamental particles." (Not Q).
3. Therefore, mechanical atomism is not true (not P).

Emergentism essentially seeks to establish the truth of premise 2 with its claim that: there exist emergent entities that cannot be explained as aggregates of their constituents (which are

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[365] Bohm and Hiley, *The Undivided Universe*, 64.
[366] Bohm and Hiley, *The Undivided Universe*, 61.

ultimately reducible to the most fundamental particles), and such emergent entities can be identified with the four criteria: **(1)** qualitative newness, **(2)** novelty, **(3)** autonomy, and **(4)** holism.

Now, I propose that the Bohmian interpretation of quantum physics effectively supports emergentism's claim that there exist irreducibly emergent entities by highlighting the quantum potential Q as a feature proper to certain quantum systems as a whole. These system's Q(s) can guide or in-form, as pools of common active information, the movement or behaviour of their constituents from the perspective of the whole. Quantum entanglement and hydrogen atoms are precisely examples of such holistic systems guided by their respective Q(s): in an entangled system, it is its quantum potential Q that binds the kinetic energies of the entangled particles together in a non-local and conserved fashion thereby imbuing their movement with an anti-correlated form. The hydrogen molecule's quantum potential Q is likewise the cause of its stability, since it binds and in-forms the protons within the molecules to attract each other at medium distances, and repulse each other at short distance.

Evidently on a Bohmian interpretation, the proper cause of these emergent entities' holisms is their respective quantum potential Q(s), which distinguish the emergent entities as "wholes guided by a pool of common information" from merely aggregate entities that are "systems constituted of independent parts guided by separate pools of information."[367] Indeed, Bohm and Peat themselves state that it is precisely this quantum potential Q that explains the "novel features"[368] of the quantum world such as holism because Q represents a "generative order"[369] from which particles can "emerge" and be "organized...into higher-level entities, such as atoms and molecules...this order organizes the particles in ways that depend crucially on the

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[367] Bohm and Hiley, *The Undivided Universe*, 61.
[368] Bohm and Peat, *Science, Order, and Creativity*, 88.
[369] Bohm and Peat, *Science, Order, and Creativity*, 193.

common pool of information in the wave function of the whole system."[370] This common pool of information Q explains why emergent entities have novel features: for Bohm, an emergent entity is irreducible to its constituents precisely because the constituents are being 'in-formed' or guided by Q as a cause that is acting 'downwardly' upon them as a whole, directing them to behave in ways that are novel. It is this downward causal power of the whole that makes the whole something over and above the determination of its constituents so that the whole exhibits a kind of autonomy, which suggests that the whole is a qualitatively new and different *kind* of reality in relation to its microphysical parts. Evidently, the existence of emergent 'wholes' undermines mechanical atomism's claim to offer an exhaustive description of the world in a reductionistic fashion. Nevertheless, mechanical atomism remains the dominate paradigm largely due to its claim that it is justified by the unparalleled success of science.

Yet, the Bohmian interpretation, if not mistaken, offers strong evidential support for emergentism because the Bohmian interpretation (1) illustrates that emergent entities do in fact exist on *scientific grounds* and (2) identifies a real feature of the world: the quantum potential Q, as the unitive principle and the explanatory cause of emergent entities and their unique features. Indeed, science has been conceived through the atomistic-mechanical ontology for a very long time, but Bohm shows that the continued progress of science demands us to see further, with a broader vision to its emergent features.

Secondly, the Bohmian interpretation and emergentism call for a broaden conception of causation to include the Aristotelian-Thomistic formal cause. Recall in **section II.3** (p.16) it was highlighted that one important feature of mechanical atomism is its emphasis of material and efficient causes and abandonment of formal and final causes. As a result, mechanical philosophers conceived efficient causation, the push and pull between material

[370] Bohm and Peat, *Science, Order, and Creativity*, 193.

corpuscles governed by laws, as the only real type of causation capable of explaining all phenomena in the universe. Yet, as discussed in section **IV. 5.3**, the Bohmian causal/ontological interpretation rediscovers formal cause as a real feature of the world.

Briefly, the function of the quantum potential Q does not depend on its strength, but rather on its "form"[371] and this is because the wave function **ψ**, from which Q is derived, is contained in "both the numerator and the denominator" of the equation for Q, which means that "*Q* is unchanged when **ψ** is multiplied by an arbitrary constant."[372] As such, the effect of Q depends "only on its overall shape,"[373] which puts the emphasis on *how* (the category of quality), rather than *how much* (the category of quantity), the quantum potential Q is. In other words, it is better to conceive quantum potential Q as a 'form' rather than a Newtonian 'force': as Bohm himself said, the quantum potential Q is "a *form* having very little energy [that] enters into and directs a much greater energy. The activity of the latter is in this way given a *form* similar to that of the smaller energy."[374]

Hence, Q is a cause capable of 'in-forming,' or, to "actively...put form into something or to imbue something with form"[375] as an active in-formation, or, in the classical language of Aristotle and the Scholastics, *formal cause*. The quantum potential Q, as just discussed, in turn plays a significant role in emergent entities like hydrogen atoms and molecules, functioning downwardly as their formal cause (the common pool of information) and the source of their unity and novel features. Hence, it is perhaps a great irony that mechanical atomism, a framework tailor-made to free science from the so-called 'occult' of Scholasticism, has become something that hinders our understanding of science by inclining our imagination of the universe

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[371] Bohm and Peat, *Science, Order, and Creativity*, 89.
[372] Bohm and Peat, *Science, Order, and Creativity*, 89.
[373] Bohm and Peat, *Science, Order, and Creativity*, 90.
[374] Bohm and Hiley. *The Undivided Universe*, 35. Emphasis mine.
[375] Bohm and Hiley. *The Undivided Universe*, 35.

toward the strictly quantifiable, forcing the human person to turn a blind eye to the great complexity of nature, reducing the world and each other to meaningless particles in motion. If Bohm and the emergentists are correct, however, it is now time to free ourselves from the boundaries of mechanical atomism: its insistence on the empirical and quantifiable is and always will be an essential part of science, but, given the quantum revolution and the growing awareness of emergence, it no longer seems feasible or perhaps even possible to confine the cosmos within the walls of mechanical atomism. It is time to broaden our horizon and look beyond mechanical atomism for an alternative fundamental ontology that is capable of including more kinds of realities, such as the 'emergent wholes,' into the realm of the fundamentally real. I propose that the contemporary Aristotelian-Thomistic metaphysics is precisely such a timely and suitable alternative that allows us to robustly affirm, articulate, and, ultimately, to better understand the reality of emergence.

Section V.5. : Aristotelian-Thomistic Metaphysics and Emergentism.

In fact, a renewed interest in Aristotelian metaphysics has been manifesting itself in contemporary academia since at least the 1970s,[376] especially surrounding the subjects of purposefulness, causal power, and emergence. For instance, quoting Moss (2009)[377], Bardini (2016) concurs that the goal of synthetic biology is to "make emerge a porous interface between analog and digital life"[378] and to recognize "new forms of presence across the analog/digital

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[376] For some of the key figures of this 'neo-Aristotelian revival," see Simpson, "From Quantum Physics to Classical Metaphysics," 24. See also: Edward Feser, *Scholastic Metaphysics: A Contemporary Introduction* (Germany: Editiones Scholasticae, 2014), 263.

[377] "To understand life is to recognize its ineluctable finality as Aristotle intended it and to recognize its thoroughgoing materiality – but how to relate the two? For Aristotle the best solution was to understand the primacy of 'substantial forms', that is, the fusion of formal and final cause, within nature as that which captures and shapes and animates materiality from within. Form and finality are inextricably linked in the living organism, and immanent in nature." - Lenny Moss, "Detachment, Genomics and the Nature of Being Human," in Newvisions of nature,ed. Martin Drenthen, Jozef Keulartz, and James Proctor (New York: Springer, 2009), 105.

[378] Thierry Bardini, "Future Life Will Be Synthetic: About the Emergence of Engineered Life, Its Promises, Prophecies and the Formal Causalities Needed to Make Sense of Them," *Social Science Information* 55, no. 3 (2016): 370. https://journals.sagepub.com/doi/abs/10.1177/0539018416638950

divide,"[379] and these new forms of presence "ought to be considered as *medium* and message, data and process, all in one. Like the substantial forms of old, their conditions of possibility should be investigated with a renewed interest for the formal causes of their modes of existence."[380]

Evidently, the Aristotelian substantial form's unique capacity to account for qualitatively different *kinds* of existence is what attracts many contemporary academics to it, especially the emergentists. For instance, Nsubuga (2022) recently argued that ontological emergence manifests in various physical and biological sciences as "Broken symmetry and phase transitions" that highlight "the irreducibility of the higher (new) entity to the lower entity ... the causal powers of the emergent properties [reveal] the fact that they are irreducible to the basal properties. This is the case of downward causation in ontological emergence."[381] Significantly, Nsubuga argues that "The formal cause defines the identity of the entity. Out of the many available and possible degrees of freedom, the formal cause selects some it actualises, thus defining the entity,"[382] and a given entity's formal cause is thus an "explanatory account for some downward causation manifestations."[383]

Similarly, Emmeche, et al. (2000) state that "the form of a given entity or process...is not reducible to effective or material causality,"[384] and that downward causation "does not involve...a strict "efficient" temporal causality...rather, the entities at various levels may enter part-whole relations," such that "the control of the part by the whole can be seen as a kind of functional (teleological) causation, which is based on...formal causation in a multinested system

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[379] Bardini, "Future Life Will Be Synthetic," 370.
[380] Bardini, "Future Life Will Be Synthetic," 380.
[381] Paul Nsubuga, "A Discussion for the Metaphysics of Downward Causation, The Case for Ontological Emergence" (PhD diss., Universidad de Navarra, 2022), 215.
[382] Nsubuga, "A Discussion for the Metaphysics of Downward Causation," 273.
[383] Nsubuga, "A Discussion for the Metaphysics of Downward Causation," 160.
[384] Emmeche, Køppe, and Stjernfelt, "Levels, Emergence," 5.

of constraints."[385] Moreover, as Tabaczek (2021) points out,[386] there are many other thinkers who likewise appeal to the Aristotelian formal cause to explain emergence, wholeness, or downward causation, including El-Hani and Pereira (2000),[387] Silberstein (2006),[388] Moreno and Umerez (2000),[389] Scott (2007),[390] Terrence Deacon,[391] etc. Hence, the Aristotelian formal cause seems to have great explanatory potential for emergentism, making it imperative that we carefully look into this kind of causation.

Section V.5.1: Potency and Act.

To understand formal cause, we need to first consider the two most fundamental principles of Aristotelian-Thomistic philosophy: **potentiality** and **actuality**.

We all experience motion or change: a person stands up after sitting down, children growing up, particles going from rest to motion, things coming in and out of existence, etc. To the ancient Megarians,[392] however, change is a curious phenomenon because they held that "a thing has a potency for acting only when it is acting, and that when it is not acting it does not have this potency."[393] The key term here is naturally '*potency*,' the ancient Greek word 'δύναμις'

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[385] Emmeche, Køppe, and Stjernfelt, "Levels, Emergence," 11.

[386] Tabaczek, *Divine Action and Emergence,* 46.

[387] Charbel Nino El-Hani and Antonio Marcos Pereira, "Higher-Level Descriptions: Why Should We Preserve Them," *Downward Causation: Minds, Bodies and Matter* 133, (2000): 118-42.

[388] Michael Silberstein, "In Defence of Ontological Emergence and Mental Causation," In *The Re-Emergence of Emergence: The Emergentist Hypothesis From Science to Religion*, ed. Philip Clayton and Paul Davies (Oxford: Oxford University Press, 2006), 205.

[389] Alvaro Moreno and Jon Umerez, "*Downward Causation at the Core of Living Organization*," in *Downward Causation: Minds, Bodies and Matter*, ed. Peter Bøgh Andersen (Aarhus: Aarhus University Press, 2000), 107, 109.

[390] Alwyn C. Scott, *The Nonlinear Universe: Chaos, Emergence, Life* (New York: Springer Science & Business Media, 2007), 6.

[391] Deacon, *Incomplete Nature: How Mind Emerged From Matter*, 2011.

[392] "The Megarians were a Greek 'Socratic' school of the fourth and early third centuries bc. After their founder Euclides, whose main doctrine was the unity of the good, the leading Megarian was Stilpo, best known for preaching the self-sufficiency of virtue. They propounded various puzzles and found objections to the possible–actual distinction, the copula and universals." - David Sedley, "Megarian School," in *Megarian School - Routledge Encyclopedia of Philosophy*, last modified 2022, https://www.rep.routledge.com/articles/thematic/megarian-school/v-1

[393] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 3, Aristotle's Text, chapter 3&4, 1, p.593.

(*Dunamis*) for strength, ability, capacity, or power.[394]

Since the Megarians held that a thing only has the potency for acting in a certain way when the thing is acting that way, it follows that a thing does not have the potency when the thing is not acting that way: for example, a man who is sitting down would not have the potency for standing up because he only has the potency of standing up when he is standing up.[395] As such, "what is standing will always stand, and what is sitting will always sit, because if it is sitting it will not get up, since it is impossible for anything to get up which has no possibility of doing so."[396] This Megarian position amounts to a denial of change[397] for it implies that nothing have the potency to be otherwise except when they are in fact being otherwise, but this is impossible, since they do not have the potency to be otherwise in the first place.

Commenting on the Megarian position, Aquinas writes: "the reason for this position seems to be that they thought that all things come about necessarily because of some connection between causes. Thus if all things come about necessarily, it follows that those things which do not, are impossible."[398] It is interesting to observe, based on Aquinas' comment, that the Megarian view astoundingly reassembles the atomistic-mechanical view of causation as a matter of 'necessary connection' between events. As such, the Megarians and the mechanical philosophers face the same problem: the so called 'necessary connections' do not explain but only describe the connections between causes and effects.

Parmenides, though more ancient, illustrated clearly the consequence of the kind of reasoning held by the Megarians and mechanical philosophers: if things cannot be other then

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[394] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 202.

[395] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 3, Aristotle's Text, chapter 3&4, 5, p.593.

[396] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 3, Aristotle's Text,chapter 3&4, 5, p.593.

[397] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 3, Aristotle's Text,chapter 3&4.

[398] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 3, 1795, p.595.

they are because they do not have the potency for being otherwise, then, change is altogether impossible because change has to come from either "what is or from what is not, both of which are impossible. For *what is* cannot come to be (because it is already), and from *what is not* nothing could have come to be."[399] Indeed, since *what already is* does not have the potency to be otherwise, and since *what is not* is nothing, from which nothing can come, it is quite impossible for any kind of change to occur, and this seems the reason why the Megarians and the mechanical philosophers had to resort to the notion of 'necessary connection' to explain change, scandalizing Locke, Berkeley, and Hume about the possibility of a science that knows why causal connections ever occur.

Aristotle disagreed with Parmenides and the Megarians because they error by denying change through "mak[ing] potency and actuality the same."[400] Instead, Aristotle holds that reality or being cannot be reduced to any one single principle but exists in many modes. Being for Aristotle is thus an analogically pluralistic notion that can be conceived in (at least) two ways: one way via his famous ten categories, and one way via potentiality and actuality, [401] with the latter distinction making change and causation intelligible.

Consider a salt particle that can be dissolved in water. The Megarians would say salt can never dissolve because it only has the potency for dissolving when it is actually dissolving. Parmenides might add that in order for the dissolved salt to exist, it needs to come from non-being, which is impossible. The mechanical philosophers would allow salt to dissolve, but would see it as resultant from a necessary law or connection without bothering explaining *why* this law

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[399] St. Thomas Aquinas, *Commentary on Aristotle's Physics*, ed. Vernon J. Bourke and Ralph M. McInerny, trans. Richard J. Blackwell, Richard J. Spath, and W. Edmund Thirlkel (Notre Dame: Dumb Ox Books, 1995), Book One, Lecture 14, The Text of Aristotle, Chapter 8, 81.

[400] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 3, Aristotle's Text, chapter 3&4, 6, p.593.

[401] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, Aristotle's Text, chapter 1, 1, p.584.

or connection is necessary. From an Aristotelian perspective, however, salt can indeed dissolve because its sodium-chloride bond has *a* "passive potency"[402] or capacity for being acted upon by the water molecule's positively charged hydrogen pole and negatively charged oxygen pole that will, respectively, attract the negatively charged chloride-ions and positively charged sodium-ions, effectively pulling their ionic bond apart. The water molecules thus also have a *potentiality* albeit a different type: *an "*active potency",[403] which is *a kind of* "actuality:"[404] a capacity to act upon the passive potencies of the sodium and chloride ions to be attracted and thus breaking their bond,[405] actualizing their' passive potentiality for being dissolved.

This distinction between potentiality and actuality enables Aristotle to uphold both change and causation: Contrary to Parmenides, change does not require being arising from non-being, but being-in-actuality arising from being-in-potentiality. Contrary to the Megarians, potentiality differs from actuality because it is a curious middle ground between being and nonbeing: it is something "still real"[406] and present in things even when not actualized. Contrary to the mechanical philosophers, causation is not the result of 'necessary connection', but the result of the actualization of the passive potencies of things[407] (e.g., salt's dissolubility), by the active potencies of something already in actuality (e.g., the water molecule's polarity that is capable of breaking salt's sodium-chloride bond), and this understanding of change via the actualization of potentiality by actuality is thus classically known as the Aristotelian *principle of causality*.[408] Therefore, both change and causation are real and rationally intelligible for Aristotle,

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[402] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, 1777, p.587.
[403] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, 1776, p.587.
[404] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 5, 1826-1829, p.604-605.
[405] David S Oderberg, *Real Essentialism* (New York: Routledge, 2007), 63.
[406] Feser, *Scholastic Metaphysics*, 33.
[407] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, 1777, 1779.
[408] See the classical expression of the principle of causality in Aquinas, *Summa Theologiae*, I, q.2, a.3: "But nothing can be reduced from potentiality to actuality, except by something in a state of actuality." See also

and as Feser (2014) highlights, Aristotle's potency/act distinction provides the very rational foundation for science[409] as the knowledge of proper (true) causes that are the real actualizers of the phenomena of nature studied by science (more on this below). The error of Parmenides, the Megarians, and, by extension, the mechanical philosophers, is thus the reduction of being to one single principle, i.e., actuality without potentiality (active and passive powers), thereby rendering actuality static ('power'or potency-less- no wonder change and causation became unintelligible for them!) without realizing that potentiality is a mode of being distinct from actuality.

The above discussion also illustrates that the relationship between potentiality and actuality is dynamic and multifaceted[410]: if potentiality is " the "principle of change,"[411] the capabilities or dispositions[412] of things for "acting ["active potency"[413]] and for being acted upon["passive potency"[414]],"[415] actuality is then the principle of "stability"[416] that grounds and actualizes potentiality, and this is why active potency is also a kind of actuality. However, actuality is hard to define because it is a fundamental concept, a "first simple notio[n]"[417]best understood via "proportion"[418]to other notions like potentiality. A helpful summary of Aristotle and Aquinas' discussion on the meaning of actuality in relation to potency[419] is provided by

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Feser, *Scholastic Metaphysics*, 105-146 for a contemporary defense for the principle of causality against the well known objections from Newtonian physics, Hume, Scotus,quantum mechanics, etc.

[409] Feser, *Scholastic Metaphysics*, 36.

[410] For a concise account of the various kinds of potency and act, see figures from Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 276-277,

[411] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, Aristotle's Text, chapter 1, 2, p.584. See also: Book Five, Lessons 14, Aristotle's Text, chapter 12, 1-5, p.342-343.

[412] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 4, 1818, p.600.

[413] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, Aristotle's Text, chapter 1, 3, p.584.

[414] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, Aristotle's Text, chapter 1, 3, p.584.

[415] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 1, Aristotle's Text, chapter 1, 3, p.584.

[416] Feser, *Scholastic Metaphysics*, 34.

[417] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 5, Aristotle's Text, chapter 6, 3, p.603. See also Aquinas' commentary on this text: 1825, p.604.

[418] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 5, 1828, p.605.

[419] See, for example, Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 7-10.

Feser (2014):

(1) "any potency is always defined in relation to act."[420] Because **potencies** are capacities for being **actual** in certain ways: e.g., the passive potency for dissolving is a potency for being actually dissolved. Active potencies are also potencies for being actually acting, e.g., for water to be **actually** dissolving salt.

(2) "a thing's potencies are *grounded* in its actualities."[421] Because the **potencies** of a thing are grounded in what it **actually** is; e.g., the salt particles' potency for dissolving is grounded in its **actuality**: its sodium-chloride bond with negative and positive poles that are susceptible to the polarity of water molecules.

(3) "a potency can be actualized only by what is already actual."[422] Because a potency, though real, does not have actuality until it is actualized. Hence, a potency lacks actuality and thus cannot actualize itself since it cannot give itself something (i.e., actuality) that it lacks. A potency thus must be actualized by something *already actual*. For example, the passive potencies of the sodium-chloride bond for dissolution cannot actualize itself but must be actualized by actual water. Active potencies are too only made actual when they are exercised by actually existent things.

(4) "act is prior to potency insofar as while there can be nothing that is pure potency -- since, if a things were *purely* potential and in no way actual, it would not exist -- there can be something which is pure act."[423] Because whilst pure actuality is that existence unlimited and divine for Aristotle and Aquinas[424] pure potency is potentiality devoid of actuality. Yet, pure

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[420] Feser, *Scholastic Metaphysics*, 38.
[421] Feser, *Scholastic Metaphysics*, 38.
[422] Feser, *Scholastic Metaphysics*, 38.
[423] Feser, *Scholastic Metaphysics*, 38.
[424] Feser, *Scholastic Metaphysics*, 38.

potency is not without significance; rather, it underlies the Aristotelian notion of prime matter.[425] This brings us to the next section.

Section V.5.2: Potency and Act as Matter and Form.

Moreover, matter and form are a particular application of potency and act to the analysis of the *intrinsic* principles of material things.[426] **Matter:** To begin, Aristotle observes that many things around us are "thaten,"[427] or that which "comes from something else as from matter."[428] For example, a wooden chest is a thaten because it is made from wood. However, if there is something that cannot be called a thaten because it is not made from any other material, this 'something' is thus "prime matter."[429] Now, prime matter is not some most fundamental or smallest materials: as discussed above in **section II.1** prime matter for Aristotle is a principle of potentiality "ultimately disposed for actuality."[430] Hence, prime matter is present in every material thing as their underlying substratum. Yet, we do not encounter prime matter in the world but rather concrete substances. For Aristotle, this means every substance must also exhibit a "form," a "specifying"[431] principle of "actuality"[432] that actualizes prime matter's potency for taking on a particular *kind* of form, resulting in a particular *kind of* a "compound"[433] or hylomorphic substance as composed of matter (*hylē*) and form (*morphē*).

Oderberg (2022) argues that Aristotle's view of materiality as (ultimately) prime matter is strongly supported by the notion of energy in contemporary physics, which understands energy

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[425] Tabaczek, "Emergence and Downward Causation," 124.
[426] Feser, *Scholastic Metaphysics*, 162.
[427] Aristotle's Text, chapter 7, 3, p.606 in Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 6.
[428] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 6, 1839, p.608.
[429] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 6, Aristotle's Text, chapter 7, 3, p.606.
[430] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 6, p.606.
[431] Aquinas, *Commentary on Aristotle's Metaphysics*. Book Nine, Lessons 6, 1843.
[432] Aquinas, *Commentary on Aristotle's Metaphysics.* Book Nine, Lessons 8, Aristotle's Text, chapter 8, 8, p.614.
[433] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 6, 1839.

as that which "can be converted from one form to another but cannot be created or destroyed."[434] Hence, energy is always "preserved through substantial transformation,"[435] such as one elementary particle transforms into another, but their underlying energy is conserved (the principle of energy conservation): it did not disappear and then reappear, but took on different forms, e.g., the forms of muon, electron, quarks, etc. Interestingly, Aristotle also understood prime matter as that which "does not cease to be"[436] during the transformation of one substance to another, because prime matter is simply the underlying "potential"[437] capable of taking on the differing forms of these substances.

Moreover, "neither prime matter nor energy exists in a free - that is, formless-state."[438] In physics, for instance, one does not encounter pure and unorganized energy; rather, energy always manifests under particular forms, including the "kinetic, thermal, potential, chemical,"[439] etc. The so-called "free energy"[440] too does not mean energy in a "pure, unorganised state," but rather the "*available* energy to do work"[441] in a given system. Significantly, prime matter too cannot exist on its own but "only exist *when conjoined* with form."[442]Based on these similarities, Heisenberg famously concluded that "The [prime]matter of Aristotle...is a kind of indefinite corporeal substratum, embodying the possibility of passing over into actuality by means of form...which is mere 'potentia,' [that] should be compared to our concept of energy.[443]

Form: Furthermore, if a thing's matter is ultimately its principle of potentiality disposed

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[434] David S. Oderberg, "Is Prime Matter Energy?" *Australasian Journal of Philosophy* (2022): 5.
[435] Oderberg, "Is Prime Matter Energy," 5.
[436] Aristotle, *Physics*, I. 9, 192a .
[437] Aristotle, *Physics*, I. 9, 192a .
[438] Oderberg, "Is Prime Matter Energy," 8.
[439] Oderberg, "Is Prime Matter Energy," 8.
[440] Oderberg, "Is Prime Matter Energy," 8.
[441] Oderberg, "Is Prime Matter Energy," 8.
[442] Oderberg, "Is Prime Matter Energy," 8.
[443] See Heisenberg, *Physics and Philosophy.*

to take on form, its form is then a principle of actuality[444] capable of bringing "completeness or perfection"[445] to the matter by actualizing its potential for being actual via a given form specifically. From an Aristotelian-Thomistic perspective, however, forms come in at least two different varieties: "substantial form" (*forma substantialis*) and "accidental form"[446] (*forma accidentalis*), and they are distinct because: "substantial form gives being absolutely to matter...whereas accidental form...gives being in a qualified sense."[447] Aquinas further explains this distinction in *De principiis naturae*:

> But existence is twofold: one is essential existence or the substantial existence of a thing, for example man exists, and this is existence *simpliciter*. The other is accidental existence, for example man is white, and this is existence *secundum quid*...that which causes substantial existence in act is called substantial form and that which causes accidental existence in act is called accidental form.[448]

Therefore, *substantial form* is what causes the existence of a particular kind of substance to be, such as a human, by bringing that substance into existence when this substantial form is conjoined to matter. For this reason, Aquinas also calls substantial form "the essence of a thing,which refers to its [substantial]form."[449] *Accidental form*, however, only modifies "something which is an actually existing [substance]"[450] already exhibiting matter and substantial form.

Accidental Form: Accidental forms are thus defined by their inability to bring some

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[444] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 8, Aristotle's Text, chapter 8, 8, p.614.

[445] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 8, 1861, p.616.

[446] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 2, 775, p.285.

[447] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 2, 775, p.285.

[448] Aquinas, *On the Principles of Nature*, 1-5.

[449] "Et alio modo dicitur substantia quod **quid** erat esse, quod pertinet ad formam." - Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 7, 1566, p.616. Emphasis added.

[450] Eleonore Stump, *Aquinas* (New York: Routledge, 2005), 38.

qualitatively new things into existence; rather, they are merely modifications of already existing things. An axe, for example, has an accidental form because it seems to be no more then an aggregate of its parts, including its wooden handle and metal head. The axe is surely a useful tool when its parts are 'modified' or combined via the form of an axe, yet, this axe does not seem to be a qualitatively new *kind* of substance; rather, it seems to be the "sum of the causal powers and properties of the constituents of the axe."[451] Accidental forms can also occur naturally, such as when stones or trees fall on top of each other, forming a pile with certain shapes. However, most accidental forms share a common characteristic: they are no more than the incidental features and modifications, of existing things without introducing qualitatively new types of existence into reality.[452]

Substantial Form: Substantial forms are defined by their ability to bring about genuine substances, which are not mere modifications of already existing things; rather, substances are concrete particulars: they are primary units of existence each with its own irreducible identity. Aquinas' Latin name for substances like this translates as "supposit," which is from the Greek term "*hypostasis*,"[453] which roughly means an individually subsisting reality. As such,substantial forms function (at least) as **(1)** a principle of substantial generation[454] (since substantial forms do not simply modify already existing substances, but cause the existence of genuine substance as they actuate matter), and **(2)** a principle of specification[455] (and also **(3)** a principle of substantial unity, since a substantial form is what causes a substance to be a unit of a particular *kind* or *specie* of existence. See below).

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[451] Stump, *Aquinas*, 44.

[452] We shall see in **Section VI** below, however, that the Scholastics do recognize a kind of accidental form: **extrinsic formal objective-specificative cause,** which can possibility explain a degree of qualitative newness/emergence even though the emergents fall short of the generation of substances.

[453] Stump, *Aquinas*, 50.

[454] Stump, *Aquinas*, 38.

[455] Stump, *Aquinas*, 38, 44-46.

The simplest cases of substance with substantial forms for Aristotle and Aquinas were the most basic material things: the elements of earth, water, fire, and air,[456] which correspond to our contemporary notion of elementary particles. The Standard Model of Particle Physics now recognizes elementary fermions, e.g., quarks, leptons, etc., and elementary bosons, e.g., photons, gluons, Higgs bosons, etc., as the most simple and basic things of the universe with no internal structures. It is disputed whether these elementary particles are substances in the Aristotelian-Thomistic sense;[457] yet, if one assumes that they are, each type of elementary particle would be an irreducible kind not composed of smaller things. However, even the elementary particles are still not 'matter as such' in the sense of energy or prime matter: recall Heisenberg's definition of matter as 'indefinite corporeal substratum.' This means that the so-called elementary particles still need to have 'forms,' such as the forms of quark, etc., as a principle of actuality that organizes their matter/energy to become particular *kinds* of elementary particles as hylomorphic substances. Now, if elementary particles' forms are causing them to exist as unique kinds of substance that are not mere modifications of pre-existing things, the elementary particles' existence would thus be substantial existence in the Aristotelian-Thomistic sense and their forms substantial form.

Virtual Presence and Substantial Form as a Principle of Unity in Substances:

However, Aristotle and Aquinas did not restrict the status 'substance' and substantial forms to only the most elementary things. For them, substance, "in the truest and primary and most definite sense of the word, is that which is neither predicable of a subject nor present in a subject; for instance, the individual man or horse."[458] Furthermore: "all substance appears to signify that which is individual. In the case of primary substance this is indisputably true, for the

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[456] Stump, "Emergence, Causal Powers," 53.
[457] See Koons. "Thermal Substances," 1-22.
[458] Aristotle, *The Categories*, trans. E. M. Edghill (Bolton: CreateSpace, 2014), Section 1, part 5.

thing is a unit."[459] What's unique about substances for Aristotle is thus their ontological 'thickness': they are genuine beings unto themselves because they exhibit a kind of unity, something that makes them truly subsisting units irreducible to a collection of accidents. The source of this unity is, of course, substantial form. Yet, it seems now we have a dilemma because the many things of our world that Aristotle and Aquinas would assign the status 'substance' and substantial form seem to be composed of smaller substances. For example, if elementary particles are substances, this would render all other existence in the world nothing but aggregates of these elementary particles, which is exactly the world of mechanical atomism.

From an Aristotelian-Thomistic perspective, however, even things seemingly composed of smaller substances, such as atoms, molecules, animals, etc., can still be genuine substances because, for example, the substantial form S of a complex substance A "confers causal powers on the whole,"[460] which means the parts of this substance, even if they were genuine substances before entering into **A**, "cease to exist as the things that they were when they are woven together"[461] by the new substantial form **S**. Yet, the parts did not magically disappear; rather, they no longer exist or are present *actually* in the new substance A as independent substances, but, as Aquinas argues in *De mixtione elementorum* via Aristotle, that they are now present 'virtually'[462] by their powers or "active and passive qualities"[463] that are to be "in-formed by a higher [substantial] form of a compound."[464]

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[459] Aristotle, *The Categories*, Section 1, part 5.

[460] Stump, "Emergence, Causal Powers,"53.

[461] Stump, "Emergence, Causal Powers,"53.

[462] "Therefore, the elements evidently do not remain in the blend by act, as body and white do; nor are they corrupted, neither the other nor both: for their **virtue** is preserved." - Thomas Aquinas, *De Mixtione Elementorum*, ed. Joseph Kenny, O.P., trans. Peter Orlowski, 59, 60, https://isidore.co/aquinas/MixtioElementorum.htm#Text: Emphasis added. See also : Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 229-230.

[463] Aquinas, *De Mixtione Elementorum*, 51.

[464] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 229. See also Christopher Decaen, "Elemental Virtual Presence in St. Thomas" *The Thomist: A Speculative Quarterly Review* 64, no. 2 (2000): 271-300. https://muse.jhu.edu/article/637009

The substantial form is thus what gives even a complex substance its distinct kind of unity, making it a holistic '*unit*' by acting upon its parts from the perspective of the whole according to its *kind*-specific nature. As Tabaczek (2019) helpfully points out,[465] this holistic and unitive power of the substantial form is captured precisely by Aquinas when commenting on various kinds of formal causes in his *Commentary on Aristotle's Metaphysics*:

> **[a]** For sometimes things are united merely by their arrangement, as the men in an army or the houses in a city; and then the whole has the role of a form which is designated by the term army or city. **[b]** And sometimes things are united not just by arrangement alone but by contact and a bond, as is evident in the parts of a house; and then their composition has the role of a form. **[c]** And sometimes the alteration of the component parts is added to the above, as occurs in the case of a compound; and then the compound state itself is the form, and this is still a kind of composition. And a thing's essence is derived from any one of these three—the composition' species, or whole.[466]

In other words, when a compound has the power to alter its components from the viewpoint of the whole, this holistic state can no longer be seen as an accidental form resultant from a mere aggregate (e.g., arrangement, contact, bond, etc.,) of its components, since an aggregate like that, by definition, should yield no qualitatively new reality. Yet, a compound capable of altering its component has attained, to use emergentism's language, novel features, or "properties and causal powers ... irreducible to those of its parts,"[467] which suggests that this compound now has its distinct substantial form as the source of this power, making it a genuine substance.

Section V.6: Aristotelian-Thomism and Emergentism in Synthesis.

Substantial form and the notion of substance as irreducible 'wholes' are what seem to

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[465] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 217-218.
[466] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 3, 779, p.287. Emphasis added.
[467] Feser, *Scholastic Metaphysics*, 168.

make Aristotelian-Thomistic metaphysics particularly attractive to emergentists because, as the various thinkers mentioned in **Section V.5.2** highlight, they provide an ontological foundation that allows emergentists to robustly articulate what emergence is and what makes something emergent over and above the microphysical realm. In this section, we shall apply A-T metaphysics and emergentism to a concrete example in an attempt to synthesize them.

Eleonore Stump (2013) provides an excellent case study of how A-T metaphysics can be applied to emergence with the example of water molecules.[468] A water molecule contains two hydrogen atoms and one oxygen atom (H_2O). In their individual states, each hydrogen atom contains one electron, and each oxygen atom contains eight electrons, "two in the innermost shell and six in the outer shell."[469] In a water molecule, however, the original organization of the oxygen and hydrogen atoms had "before their bonding together is replaced by the new organization of the water molecule."[470] Specifically, within a water molecule, the two hydrogen atoms' electrons will pair up with two electrons from the oxygen atom to form two "shared electron pairs,"[471] or covalent bonds. Since electrons are negatively charged, they repulse each other, and the unbonded electrons of the oxygen atom tend to "remain closer to the oxygen atom" and "exert a stronger repulsion against the two covalent bonding pairs"[472] of electrons, pushing the bonded electron pairs along with their connected hydrogen atoms closer to each other[473] toward one side of the water molecule. The covalent bonds between the hydrogen and

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[468] Stump, "Emergence, Causal Powers," 55-62.
[469] Stump, "Emergence, Causal Powers," 55.
[470] Stump, "Emergence, Causal Powers," 55.
[471] Stump, "Emergence, Causal Powers," 55.
[472] Libretexts, "The Bonds in Water," Chemistry LibreTexts, July 14, 2020, https://chem.libretexts.org/Bookshelves/Organic_Chemistry/Map%3A_Organic_Chemistry_(Bruice)/01%3A_Electronic_Structure_and_Bonding_(Acids_and_Bases)/1.11%3A_The_Bonds_in_Water#:~:text=In%20water%2C%20each%20hydrogen%20nucleus,into%20two%20non%2Dbonding%20pairs.
[473] Stump, "Emergence, Causal Powers," 56.

oxygen atoms result in an uneven charge distribution in the water molecules[474]: its oxygen side is negatively charged and its hydrogen side positively charged. This uneven charge distribution gives the water molecule A a unique ability to form a hydrogen bond[475] with another water molecule B because A's positively charged hydrogen side can now attract B's negatively charged oxygen side thereby forming the hydrogen bond.[476]

Stump argues that the uneven charge distribution of the water molecule is a "systems-level property"[477] that confers the causal power of forming hydrogen bond upon the molecule as a whole, which suggests that water is irreducible to a mere aggregate of its constituents, the hydrogen and oxygen atoms, for two major reasons: **(a)** Water is not a sum of its hydrogen and oxygen atoms because *their original configurations they had in isolation "have to be replaced by a new configuration* that configures all the matter of the molecule. In the whole that is the water molecule, neither the oxygen nor the hydrogen atoms retain the configurations they had earlier[478] (as just discussed above that an Aristotelian-Thomist would point out here that the hydrogen and oxygen atoms in fact no longer exist as independent substances in the water molecule, since their substantial forms have been altered or corrupted. As such, they now are only present in the water molecule virtually by their powers[479]). **(b)** a water molecule has systems-level properties that give it causal powers proper to the whole (e.g., forming hydrogen bonds), which "is not a simple sum of the causal powers of the atoms that are the components of the molecule. *By themselves, even with their causal powers added together, those atoms could not form hydrogen bonds."*[480]

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[474] Stump, "Emergence, Causal Powers," 56.
[475] Stump, "Emergence, Causal Powers," 57.
[476] Libretexts, "Hydrogen Bonds."
[477] Stump, "Emergence, Causal Powers," 57.
[478] Stump, "Emergence, Causal Powers," 58.
[479] Thomas Aquinas, *De Mixtione Elementorum*, ed. Joseph Kenny, O.P., trans. Peter Orlowski, 59, 60, https://isidore.co/aquinas/MixtioElementorum.htm#Text: Emphasis added. See also : Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 229-230.
[480] Stump, "Emergence, Causal Powers," 58. Emphasis mine.

Stump further argues that the case of water molecules illustrates and supports the Aristotelian-Thomistic notion of substantial form[481]: recall that substantial form was defined in **Section V.5.2** as **(1)** a principle of substantial generation, **(2)** a principle of specification, and **(3)** a Principle of Substantial Unity.

Now, given the two reasons above, Stump argue for the presence of a substantial form in the water molecule[482]: water's unique features suggests that it is a qualitatively distinct reality with a distinct nature or principle of existence proper to itself, which is of course its substantial form. The substantial form of the water molecule would then be responsible for its **(1)** coming-to-be or substantial generation and **(2)** specification as well as its **(3)** substantial unity, since, on an Aristotelian-Thomistic interpretation, it is the water molecule's substantial form that, as a principle of actuality, acts upon its constituents to give them their new configurations in the compound state from the viewpoint of the whole, making the whole molecule a true individual "**unit**."[483]

Section V.6.1 : Aristotelian-Thomism and Emergentism in Synthesis: Emergence's Four Criteria as Four Causes.

Crucially, Stump (2005) argues that substantial form can effectively account for emergence, which she defines as follows: "a whole...W is an emergent thing if and only if the properties and causal powers of W are not simply the sum of the properties and causal powers of the constituents of W when those constituents are taken singillatim, outside the configuration of W."[484] For example, on Stump (2013)'s account, a water molecule is emergent by virtue of its systems-level properties of uneven charge distribution, the ability to alter the configurations of

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[481] Stump, "Emergence, Causal Powers," 57.
[482] Stump, "Emergence, Causal Powers," 57.
[483] Aristotle, *The Categories*, Section 1, part 5.
[484] Stump, *Aquinas*, 43.

its constituents (the oxygen and hydrogen atoms), and its causal power to form hydrogen bonds because all three of these features are proper to the molecule as a whole and are irreducible to the features of its constituents taken singillatim.[485]

This definition of emergence by Stump corresponds well with our above discussed four criteria of emergence (**Section V.2**): **(1) Qualitative Newness of Emergents, (2) Novelty, (3) Autonomy, and (4) Holism-Downward Causation.** For instance, the water molecule's unique features seem to be particular instances of our fourth criterion for emergence: **Holism-Downward Causation.** Specifically, the ability to alter its component parts' configurations is a power of the water molecule as a whole[486] that acts in a "top-down"[487] fashion upon its constituents, and such 'top-down' action seemingly fulfills D.T. Campbell's definition of downward causation as "the causation of lower-level effects [e.g., the alternation of the component oxygen and hydrogen atoms] by higher level entities [e.g., the water molecule]."

Now, the value of Aristotelian-Thomistic metaphysics to emergentism lies in the former's ability to explain the ontological reality underlying the phenomenon of emergence: to open emergence's black-box, as it were, via the notions of substance and substantial form, allowing the emergentist to articulate and explain exactly why an emergent entity is truly novel and irreducible to its constituents. To see how, suppose a skeptic gives the following critique of emergentism:

1. An emergent entity **W** like a water molecule is emergent with respect to its constituents or "lower-level emergence base"[488] **B** (e.g., the oxygen and hydrogen atoms) on account of its unique features **F**, e.g., its supposedly novel and

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[485] Stump, "Emergence, Causal Powers," 61.
[486] Stump, "Emergence, Causal Powers," 62.
[487] Stump, "Emergence, Causal Powers," 62.
[488] Paoletti and Orilia, "Downward Causation," 3.

irreducible features like downward causation.

2. However, if emergent entities like the water molecule after all had to come from their lower-level emergence base **B**, this suggests that the emergence base **B** is ultimately causing the unique features of the water molecule **F**, which further suggests that the so called novel and irreducible features of emergent entities are, after all, simply resultant effects of the emergence base **B**.
3. If emergent entities only exhibit such resultant features from their emergence base without truly novel and irreducible features, this means an emergent entity is not emergent after all but merely resultant. To put it simply, if W causes B, and B causes F, then, the true cause of F is still W, whereas B seems to be nothing more than a resultant effect of W.[489]

This argument is of course based on the famous critique of emergentism offered by Jaegwon Kim (1993), which is often acknowledged as a fundamental difficulty of emergentism.[490]

However, Aristotelian-Thomistic metaphysics is capable of offering a strong defense of emergentism against the Kim style critique. To begin, consider the following scenario: suppose **Alice** and **Bob** got married and give birth to a child, **Charlie** with a unique personality **P.** Would it be correct to say that since Alice and Bob gave birth to Charlie, Charlie's personality really belongs to Alice and Bob, and that Charlie and his personality are merely resultant from Alice and Bob? If one follows Kim's argument, it is not obvious why one cannot affirm that both Charlie and his personhood are indeed reducible to the emergent base Alice and Bob.

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[489] Paoletti and Orilia, "Downward Causation," 3.

[490] Jaegwon Kim, "Making Sense of Emergence," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition* 95, no. 1/2 (1999): 3-4. http://www.zeww.uni-hannover.de/Kim_Making%20Sense%20Emergence.1999.pdf.

An Aristotelian-Thomist, however, would say Charlie and his personhood are surely *not* reducible to his parents because though **Alice** and **Bob** might have given Charlie his genetic material as *efficient* causes, this does not mean that Charlie is not a distinct Aristotelian **substance** on his own. Instead, Charlie can indeed be a substance or genuine 'unit' of existence exhibiting a strong principle of substantial unity that is his own substantial form if Charlie exhibits features not simply reducible to his DNA but unique to his person as a whole. Interestingly, contemporary research on epigenetics seems to support the view that we are more than our genes because it is discovered that childhood experience, including "nutritional, microbial, and psychosocial exposures" can leave "biochemical marks" on our "genome that affect gene expression," which can influence "levels of inflammation in adulthood—an important risk factor for multiple diseases of aging."[491] Hence, humans are not simply products of our DNA because a person's holistic experience in life can in fact alter how our DNA functions, which suggests that the entire human organism is capable of affecting our constituents, in a 'downward' fashion, from the standpoint of the whole.

For an Aristotelian-Thomist, downward causal powers like this in a thing are strong signs for the presence of a substantial form[492], because, as discussed above, that substantial form is a principle of actuality that makes a thing a genuine 'whole' with the distinct power to alter its "component parts"[493] according to its nature. On an A-T account, therefore, Charlie is irreducible to his parents and their genetic material by virtue of his substantial form that makes him a distinct substance with holistic, or in Stump's terms, systems-level properties and top-down

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[491] Thomas W., McDade, Calen Ryan, Meaghan J. Jones, Julia L. MacIsaac, Alexander M. Morin, Jess M. Meyer, Judith B. Borja, Gregory E. Miller, Michael S. Kobor, and Christopher W. Kuzawa, "Social and Physical Environments Early In Development Predict DNA Methylation of Inflammatory Genes In Young Adulthood," *Proceedings of the National Academy of Sciences* 114, no. 29 (2017): 7611-7616.

[492] Feser, *Scholastic Metaphysics*, 168.

[493] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 3, 779, p.287.

causal powers.[494] This Aristotelian-Thomistic analysis also applies to physical and chemical phenomenon like a water molecule, as discussed earlier. Aristotelian-Thomistic metaphysics can thus offer a rebuttal to Kim's argument: an emergent entity is irreducible to its lower level emergent base by virtue of its substantial form that makes the emergent entity a distinct substance capable of altering its constituents from the perspective of the whole. On this A-T interpretation, therefore, the heart of emergentism is really a re-discovery of the **Aristotelian substance**: granting an entity the status 'emergent' amounts to acknowledging that it is a real 'unit' of existence in the sense of an Aristotelian substance with a qualitatively distinct nature irreducible to a mere aggregate of its constituents, with this distinct nature being its essence or substantial form. Now, the critic of emergentism can of course press the same objections again, and argue that the distinct substance nevertheless comes from its emergent base, etc. This strategy fails here, however, because on an Aristotelian-Thomistic account, a substance is already a distinct 'unit' of existence by virtue of its substantial form, and such a unit is henceforth irreducible to another 'unit' with another substantial form. As such, whatever realities that a substance receives from its emergent base, the substance only received them as *matter* or *potentiality* to be configured or acted upon by its substantial form according to its kind-specific nature. The reductionist slogan 'the whole is nothing but the sum of its parts' behind the Kim-style criticism is thus guilty of an ambiguity: the whole may seem no more than its parts *according to its **matter***, but not *according to its substantial **form***.

The Aristotelian-Thomistic Substantial form is thus the fundamental reality underlying

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[494] The coming-into-existence of an emergent entity, on an A-T analysis, is in some ways similar and in some ways dissimilar to the birth of Charlie. Like the generation of Charlie, an emergent entity truly came into existence via a substantial form that makes it a distinct substance after a mixing of its prior elements (which is the point that Charlie's example can hopefully help to illustrate). Unlike the generation of Charlie, however, the prior elements of the emergent entity will likely be still present in the emergent entity if only virtually after it came into existence, whereas Charlie's parents will still be independent substances after giving birth!

our fourth condition for emergence: (4) **holism-downward causation**[495] by virtue of being the formal cause that is the source of the substantial unity of an emergent substance. Now, recall that it was discussed in **section II.1-3** that the causal pluralism of Aristotle and Aquinas recognizes at least four causes. Interestingly, Humphreys (2016)[496] also states four criteria of emergence which are the basis of my criteria for emergence.

I propose it is no accident that Humphreys lists these four criteria because they in fact correspond to the four causes of emergent entities. Specifically, we have already seen that the fourth criterion **holism-downward causation** corresponds to the **formal cause** of an emergent entity/substance as its substantial form, which, by configuring matter thereby bringing into being a distinct substance as an emergent entity with respect to its constituents, functions as the principle of intrinsic unity for that substance and the source of whatever holistic systems-level features and top-down causal powers that the substance exhibits. Hence, holism-downward causation is really a way of describing the irreducible effects of the substantial form of an emergent substance.[497]

Next, the second criterion of **novelty** corresponds to the **material cause** in the sense that what 'novelty' signifies here is really the distinct features (e.g., the systems-level properties of an emergent entity) resulting from the subtle relationship between the form and matter of an emergent entity. To begin, recall that something **E** is "**novel** with respect to a domain **D** just in case **E** is not included in the **closure** of **D** under the closure criteria **C** that are appropriate for D."[498] The power of a water molecule to form hydrogen bonds, for example, is a novel power of the whole molecule that is not included in the closure of its constituents, i.e., the hydrogen and

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[495] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 249-251.
[496] Humphreys, *Emergence: A Philosophical Account*, 27-37.
[497] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 250.
[498] Humphreys, *Emergence: A Philosophical Account*, 29. Emphasis added.

oxygen atoms because "By themselves, even with their causal powers added together, those atoms could not form hydrogen bonds."[499]

Yet, a critic may raise a challenge that, for example, the water molecule's holistic power of forming hydrogen bonds is still manifested "in those lower-level properties."[500] For instance, the water molecule still has to form hydrogen bonds with another water molecule through its oxygen atom pole with its negative charge, even though this is something that the oxygen atom cannot do by itself unless it is "organized into the whole"[501] of the water molecule. In this case, the ability to form hydrogen bond may not be that novel after all, since it can simply be the case that the oxygen atom has been somehow 'jacked up' from being a part of the organization of the water molecule.

An Aristotelian-Thomistic response to this challenge, however, would point out that such criticism does not take into account the kind of fact pointed out above by Stump that within the water molecule, the configurations that the oxygen and hydrogen atoms had in isolation "have to be replaced by a new configuration that configures all the matter of the molecule. In the whole that is the water molecule, neither the oxygen nor the hydrogen atoms retain the configurations they had earlier."[502] What this means, in the technical language of A-T philosophy, is that the substantial forms of the hydrogen and oxygen atoms (if they are indeed genuine substances) have been corrupted, which entails that the oxygen and the hydrogen atoms in fact no longer exist *actually* as individual substances "when they are woven together"[503]in the water molecule but, as pointed about above, are only present within the water molecule virtually by their powers.

As such, the water molecule's systems-level ability to form hydrogen bond is thus indeed

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[499] Stump, "Emergence, Causal Powers," 58.
[500] Stump, "Emergence, Causal Powers," 60.
[501] Stump, "Emergence, Causal Powers," 60.
[502] Stump, "Emergence, Causal Powers," 58.
[503] Stump, "Emergence, Causal Powers," 53.

a novel feature in relation to the original features of the hydrogen and oxygen atoms taken singillatim outside of the water molecule, given that this ability does not come from the aggregation of the features of the hydrogen and oxygen atoms (since they no longer exist as substances within the water molecule) but the result of the substantial form of the water molecule that is configuring "all the matter of the molecule"[504] and is conferring "causal powers on the whole" of the water molecule.[505] What about the oxygen and hydrogen atoms, then? Though no longer substances, they are still present virtually via their powers and, as Aquinas describes it, "the proximate matter"[506] (more on this below) of the "mixed bodies"[507] that they are now a part of, and that mixed body happens to be the water molecule in this case.

Novelty thus turns out to be a multifaceted criterion for emergence: it certainly signifies those holistic and system-level properties of an emergent entity first and foremost. Yet, there cannot be a new unless there is an old, which, at least within the case of the water molecule, turns out to be those constituents, e.g., the hydrogen and oxygen atoms, that, though once existing as individual substances, are now only present in the new substance virtually to be (re)configured by the water molecule's new substantial form, which is indeed the seat and origin of the water molecule's holistic and system-level properties. Novelty thus also signifies this linkage between the substantial form and those distinct properties characteristic of this emergent entity and the status of its constitutive elements as virtually present qualities and "proximate

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[504] Stump, "Emergence, Causal Powers," 58.

[505] Stump, "Emergence, Causal Powers," 53.

[506] Aquinas, *Summa Contra Gentiles*, II, 90, 5.

[507] "Quanto aliquod corpus est propinquius materiae primae, tanto est ignobilius: utpote magis in potentia existens, et minus in actu completo. Elementa autem ipsa sunt propinquiora materiae primae quam corpora mixta: cum et ipsa sint mixtorum corporum materia proxima. There is also the fact that the nearer a body is to prime matter, the less noble it is, being more in potentiality and less in complete act. The elements, however, are nearer than mixed bodies to prime matter, since they are the proximate matter of mixed bodies." Aquinas, *Summa Contra Gentiles*, II, 90, 5.

matter"[508] (more on this below).

One more conundrum, however, is the Aristotelian-Thomistic principle that substantial form exclusively configures prime matter (and not second matter) so as to bring into existence a substance rather than a collection of substances.[509] The above description of the (once) hydrogen and oxygen atoms as now the proximate or secondary matter (of the water molecule) may seem to be a confusion between prime and secondary matters because if they are indeed proximate matter, this seems to suggest that they are still actualized by their proper forms and are therefore not prime matter that is configured by the substantial form of the water molecule. One possible solution to this difficulty, however, may be that insofar as the hydrogen and oxygen atoms were once substances actualized by substantial forms, they did not enter the compound water molecule as prime matter but as "physical substrates,"[510] i.e., already organized proximate/secondary matter.[511] Yet, once the substantial forms of the hydrogen and oxygen atoms are corrupted when the compound water molecule comes into existence, the underlying primary matter that previously 'belonged' to the hydrogen and oxygen atoms has thus lost its form and is now actualized by the new substantial form of the water molecule.[512]

The third criterion **autonomy** corresponds to the **efficient cause**. Recall in **section II.3** that efficient cause was defined as any effective agents that produces an effect. The emergent entity is thus an efficient cause in the sense that it is a true 'unit' of existence or an Aristotelian substance capable of acting or to be acted upon on its own account with its distinct causal powers

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[508] Aquinas, *Summa Contra Gentiles*, II, 90, 5.

[509] Aquinas, *On the Principles of Nature*, 3.

[510] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 223.

[511] "secondary (proximate) matter ... is perceptible to our senses and quantifiable" - Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 6.

[512] This solution seems to be also suggested by Tabaczek when he states that: "according to Aquinas such physical substrates, defined as proximate or secondary matter, can indeed enter and be released from compounds, but both changes in question are substantial changes in which the substantial form of a given substrate is first corrupted and then retrieved" - Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 223.

from its substantial form. A water molecule, for example, is an efficient cause unto itself when, for example, it exercises its causal power as a holistic entity to form hydrogen bonds with other water molecules. Autonomy thus highlights the ontological status of an emergent entity as a true causal agent on account of itself irreducible to some aggregate features of its environment or constitutes.

To be sure, one may reasonably point out that the seat of an emergent entity's autonomy is its substantial form, which makes the entity an autonomous unit of existence even apart from its causal interactions with other things. True enough. Yet, one of the key Aristotelian-Thomistic principles, that is, actions follow from being, or "*agere sequitur ad esse in actu*"[513], reflects a dynamic understanding of existent things that is characteristic of Aristotle and Aquinas, that is, for a given existent thing, it does not just exist statically like the atoms of mechanism; rather, it is also a dynamic causal agent that tends to 'act' in a way that follows from its nature. This connection between being and action is expressed by Aquinas cogently: "Moreover, if to act is the result of a being which is in act, it is inappropriate for a more perfect act to be deprived of action. But the substantial form is a more perfect act than accidental form. So, if accidental forms in corporeal things have their proper actions, by all the greater reason the substantial form has its proper action."[514] As such, one may argue that the autonomy of an emergent entity, whilst having its seat and source in its nature or substantial form, is at the same time more fully expressed or manifested in its causal interaction with other things precisely as it is operating in act as an efficient cause.

The last criterion **qualitative Newness** corresponds to the **final cause.** Recall that final

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[513] Aquinas, *Summa Contra Gentiles*, III, 69, 20.

[514] "Si agere sequitur ad esse in actu, inconveniens est quod actus perfectior actione destituatur. Perfectior autem actus est forma substantialis quam accidentalis. Si igitur formae accidentales quae sunt in rebus corporalibus habent proprias actiones, multo magis forma substantialis habet aliquam propriam actionem" -Aquinas, *Summa Contra Gentiles*, III, 69, 20.

cause was defined as "a natural tendency of things to actualize their potencies, i.e. to realize what is proper to their nature"[515](**Section II.3**). An emergent entity's final cause is therefore to exist as the qualitatively new and emergent existence that it is through participating in being and interacting with things around it as a particular causal agent through the actualization of its diverse potentialities rooted in its substantial form. To use the water example one last time, the so called "anomalous properties" of water, such as its "strong surface tension, its hydrophobic effect...and its ability to act as a solvent for other substances,"[516] are precisely the results of the actualizations of water molecules' natural potentiality to form hydrogen bonds, which in turn are crucial for life. The distinct existence of an emergent entity is thus summed up in its final cause, the 'cause of causes' because it is in the final cause that the realities of all the other causes are made manifested: the **material cause (novelty)** refers to the dynamic relationship between the matter of the emergent entity with its **formal cause (holism-downward causation)**, which in turn provides the substantial being and causal powers that allows the emergent entity to exist as a genuine **efficient agent (autonomy)** that can 'live out' its existence as its **final cause (qualitative newness)**. The four criteria of emergence are thus the four causes of emergent substances, summing up their internal explanatory principles that make them the kind of realities that they are.

Section V.7 : Summary and Conclusion. If the proceeding discussion is not mistaken, it is hoped that this essay has demonstrated in **Section V** that Aristotelian-Thomistic metaphysics is of significant value to emergentism for at least three distinct yet interrelated reasons.

Firstly, with its notions such as **substance** and **substantial form**, Aristotelian-Thomistic metaphysics enables the emergentists to robustly understand and articulate emergence in an

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[515] Tabaczek, "Emergence and Downward Causation," 131.
[516] Stump, "Emergence, Causal Powers," 55.

ontologically intelligible fashion that affirms the novelty and irreducibility of emergent entities insofar as they are distinct hylomorphic composites. **Emergence**, on this Aristotelian-Thomistic interpretation, is thus the irreducible existence of an **Aristotelian substance**, a genuine subsisting unity of existence with a substantial form irreducible to its constituents. To emerge is thus to exist via a substantial form. To be emergent is thus to be an Aristotelian substance with a substantial form.

Secondly, with its doctrine of **four causes**, Aristotelian-Thomistic metaphysics reveals that the four criteria of emergence in fact correspond to the internal principles or causes of emergent substances upon which their being and becoming depend, granting ontological justification for and intelligible to the criteria of emergence.

Thirdly, as discussed above , an **application** of Aristotelian-Thomistic metaphysics allows the emergentists to defend emergence against Kim-style critiques: since the substantial form of an emergent entity guarantees its qualitatively distinct existence as a genuine unit, this entity is thus by no means reducible to other realities, even its emergent bases that in reality have merely given *matter* to be acted upon by the emergent entity's own substantial form.

As such, the Aristotelian-Thomistic metaphysics should be of great interest and benefit to proponents of emergentism because of its adaptability to modern scientific research on emergence as well as its philosophically profound capacity to illuminate the principles and causes of being as substances, which, as Aristotle and Aquinas argued long ago, are indeed primary cases of being.[517]

With Aristotelian-Thomistic metaphysics and emergentism held in synthesis, this project has one last major goal left to accomplish, that is, to illustrate that the Bohmian

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[517] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Seven, Lessons 1, Aristotle's Text, Chapter 1&2, 1-4, p.424.

causal/ontological interpretation of physics provides concrete evidence for the claims of emergentism and Aristotelian-Thomistic metaphysics that there exist irreducibly emergent entities in nature.

Section VI: **The Bohmian Causal/Ontological Interpretation of Physics, Emergence, and Aristotelian-Thomistic Metaphysics in Synthesis.**

As introduced in **Section IV.5.3,** the Bohmian Interpretation views a quantum particle like an electron as "never separated from a new type of quantum wave field that belongs to it and that fundamentally affects it [e.g., to direct the particles' behavior]. This quantum field, $\psi(x,t)$, satisfies Schrödinger's equation, just as the electromagnetic field satisfies Maxwell's equation."[518] The action of a given **quantum wave field** upon a given **particle** is defined as the **quantum potential Q**, given by the equation[519]:

$$Q = \frac{-\hbar^2}{2m}\frac{\nabla^2 R}{R} \qquad \text{where } R = |\psi|^2$$

Now, as mentioned above (in the thesis statement (p.6) and p.94), what makes the Bohmian Interpretation particularly significant to this essay is **(1)** its ability to provide evidential support for the claims of **emergentism** and **Aristotelian-Thomism** that there exist irreducibly emergent phenomena (e.g., substances) in nature; and **(2)** its potential for being held in synthesis with an Aristotelian-Thomistic metaphysics. We shall proceed to illustrate these two claims.

To begin, we have seen that an emergent entity is characterized by its four causes/ criteria: material cause (novelty), formal cause (holism-downward causation), efficient cause/agent

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[518] David Bohm, Basil J. Hiley, and Panayiotis Nicos Kaloyerou, "An Ontological Basis for the Quantum Theory," *Physics Reports* 144, no. 6 (1987): 325. https://casinoqmc.net/local_papers/bohm_hiley_kaloyerou_1986.pdf. Emphasis added.

[519] For further details of and the mathematical justification for this equation, see Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 325. and this essay, 84.

(autonomy), and final cause (qualitative newness).[520] Significantly, the Bohmian Interpretation of the quantum theory captures precisely certain holistic phenomena describable via these four causes/criteria of emergent entities.

Section VI.1.: Double-Slit Experiment:

Consider again the **double-slit experiment**. As discussed earlier in **section IV**, a crucial finding of this experiment is that "the opening of a second slit can prevent a *separate* and *independent* quantum from reaching certain dark points in the pattern which it could reach if that slit were closed. Hence, *even an individual quantum shows some wave-like properties*."[521] Whilst this wave-particle duality remains a mystery for many, Bohm provides a highly original and innovative solution:

> while the particle can only go through one slit or the other, the wave goes through both. On the outgoing side of the slit system, the waves interfere to produce a complex quantum potential...[that exerts] a strong force on the particle. The particle is thus deflected, even though no ordinary type of force is acting. The movement of the particle is therefore modified.[522]

Importantly, Bohm's interpretation is not a return to the older atomist paradigm of classical physics that views the 'fundamental particles' as simple and structureless.[523] Rather, because quantum particles like electrons can be affected by their quantum wave fields "in an extremely subtle and dynamic way,"[524] this suggests that the particles exhibit a highly complex inner structure "at least comparable to that of a radio,"[525] since the quantum particles can receive signals (See **section IV.5.2**.) from the wave fields, which in turn direct the behaviour of the

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[520] See Section V of this essay.
[521] Bohm, *Causality and Chance In Modern Physics*, 73.
[522] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 326-327.
[523] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 326.
[524] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 326.
[525] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 328.

particles through giving form or in-forming[526] the particles as "active information."[527]

The notion of active information thus plays an important role in the Bohmian Interpretation. We have seen in **section IV.5.2** that Bohm defines active information as "a **form** having very little energy [that] enters into and directs a much greater energy. The activity of the latter is in this way given a **form** similar to that of the smaller energy."[528] Information is thus for Bohm any energy that in-forms or to "actively...put[s] form into something or to imbue something with form."[529] This notion of information enables Bohm to analyze and articulate the double-slit experiment in terms of wholeness: in fact, it was Niels Bohr's famous conviction[530] that quantum phenomena like the double-slit experiment form "*a singly indivisible system.*"[531] For Bohr, the fact that measured objects, such as the behaviour of the electrons in the double slits experiment, can be determined by its environment, such as the status of the slits, and sometimes even the measuring apparatus for when the uncertainty principle applies, means that a given quantum experiment set-up, including the measured object, its environment, the measuring apparatus, and even the observer, etc., must be "united by an indivisible quantum...[as] a single indivisible entity which cannot be analysed (even conceptually) into more elementary parts."[532]

For Bohm, however, the undivided wholeness of quantum phenomena like the double-slit experiment need not be unintelligible and "arbitrary and lawless;"[533] rather, it can be understood via the notion of information involved in the interaction between the quantum wave fields and their corresponding particles. For instance, the behaviour of the electrons involved in the double

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[526] Bohm and Hiley, *The Undivided Universe*, 35.
[527] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 327.
[528] Bohm and Hiley, *The Undivided Universe*, 35.
[529] Bohm and Hiley, *The Undivided Universe*, 35.
[530] Niels Bohr, *Essays 1958-1962 on Atomic Physics and Human Knowledge* (Woodbridge: Ox Bow Press, 1963).
[531] Bohm, *Causality and Chance In Modern Physics*, 89.
[532] Bohm, *Causality and Chance In Modern Physics*, 89.
[533] Bohm, *Causality and Chance In Modern Physics*, 89.

slit experiment is indeed determined by the whole experimental environment. Yet, this wholeness can be intelligibly understood as resulting from "each particle respond[ing] to information from the entire environment...each particle goes through only one of the slits, and yet its motion is fundamentally affected by information coming from both slits"[534] because of the guidance effect exerted upon the particles by their quantum wave fields that travel through both slits, resulting in a wave interference that, like a water wave, deflects the particle, causing it to travel via only certain trajectories.[535] As such, it is the quantum wave fields that, having been in-formed by their interaction with the slits, in-formed the particles to behave like waves.

The Bohmian interpretation of the double slit experiment is thus straightforward: a form having energy (the quantum wave fields), as active information, directs or in-forms another energy (the particles). The wholeness of the experiment is thus the result of this highly subtle and complex interaction between all the elements involved within this experiment that gives its components unique features that "One has therefore to consider the whole of the relevant experimental solution, to understand what happens in each case."[536] One significant implication of this interpretation is that it highlights that the electrons can only exhibit certain unique features as part of this whole experimental environment but not individually. For instance, an electron as a particle (at least on Bohm's interpretation) is usually without wave-like behaviors. Situated in the experiment, however, the electron behaves like a wave when a second slit is open, and this, for Bohm, is caused by the particle's interaction with the information coming from the slits and the wave fields, and even more complex information can be involved in this experiment such as "chaotic thermal disturbances."[537]

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[534] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 329.
[535] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 326-327.
[536] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 329-330.
[537] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 329.

Thus, one may, following Bohr and Bohm, reasonably attribute a degree of **holism** to the double-slit experiment with the added emphasis that this experimental-whole has a degree of **downward causation** insofar as this experimental whole, which consists of the complex interaction between all of its components, is capable of determining the features of its components, namely, causing the electrons to exhibit wave-like behaviors. This **holism-downward causation** of the double-slit-experiment is of course our most essential criterion of emergence (**Section V.2. & V.6.1.**), which may be a sign that a double-slit experiment is in some sense an emergent entity with respect to its constituents. After all, it was Kronz and Tiehen (2002)'s well known argument that emergent quantum systems are marked by a "continual essential interaction," and such links may be "so robust that it is no longer meaningful to talk about components that are parts of a compound, meaning that there are components only with reference to what existed prior to the interaction and what exists after the interaction has ceased."[538] In this case, the "continual essential interaction" is supplied by the connection between the particles, the wave field, the slits, and the rest of the experimental set-up and this connection in turn alters the features of its components, changing their behaviors to the extent that they can no longer be understood individually. Bohr and Bohm thus highlighted the wave-like behaviour of the electrons as only understandable in relation to the whole experiment. If this is the case, then, both the **holism-downward causation** and the **novelty** criteria for emergence are fulfilled by the double-slit-experiment, as it is the holistic source of the electrons' novel wave-like behaviour, which, to use Stump (2013)'s term, is a "systems-level property"[539] that the electrons cannot exhibit outside of the configuration of the experiment. The experiment also fulfills the other two criteria for emergence to some extent because, as especially highlighted by

[538] Kronz and Tiehen, "Emergence and Quantum Mechanics," *Philosophy of Science* 69, no. 2 (2002): 340.
[539] Stump, "Emergence, Causal Powers," 57.

Niels Bohr, it now has to be considered as a unique entity, an undivided whole.

One difficulty remains: for as argued above in **Section V.5.2-V.7**, an emergent entity is an irreducible Aristotelian substance exhibiting a particular substantial form as its intrinsic source of unity, systems-level properties, and downward causal powers. Yet, a double-slit experiment, though exhibiting a degree of unity, does not appear to be a substance but a rather 'tightly' connected aggregate after the fashion of an accidental form. This 'difficulty,' however, turns out to be an opportunity to further explore the connection between Bohm, emergence, and Aristotelian-Thomism.

During the medieval and modern times, the Scholastics had further developed Aristotle's original theory of four causes. As Deely (2001) points out, the Scholastics represented by John Poinsot (1589-1644), better known as John of St. Thomas, had further expanded the four causes to seven or eight causes (depending on how one counts).[540] This was because a more detailed causal analysis was required to, for example, distinguish between "intrinsic final causality," which refers to the inherent tendency for an instance of existence to be what it is, and "extrinsic final causality,"[541] which is an external purpose imposed onto a thing that is outside of what it inherently is, such as using chopsticks for eating even though chopsticks cannot eat. Another distinction was made between "intrinsic formal causality,"[542] which refers precisely to substantial forms as the intrinsic source of unity of Aristotelian substances, and "extrinsic *exemplary* formal causality, also called "ideal causality," which refers to "a formal pattern or series of relations...introduced from outside the materials manipulated, unlike the natural "formal

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[540] See John Poinsot's 1632 work *Artis Logicae Secunda Pars*, Questions 17, 21, and 22, as well as his 1633 work: *Naturalis Philosophiae Prima Pars*, Questions 10-13 as noted in John Deely, *Four Ages of Understanding: The First Postmodern Survey of Philosophy From Ancient Times To the Turn of the Twenty-First Century* (Toronoto: University of Toronto Press, 2001), 633.

[541] Deely, *Four Ages of Understanding*, 632.

[542] Deely, *Four Ages of Understanding*, 632.

cause" of Aristotle which unfolds by organizing its material from within."[543]

Yet another type of extrinsic formal cause is what the late Scholastics called "***specificative or objective*** **causality**,"[544] which was utilized by the Latin-Scholastic tradition to account for and explain the "actions of signs,"[545] a "most original notion separating the onset of indigenously Latin philosophy from all that had gone before in Hellenic thought."[546] Briefly, the Latin notion of the sign was first proposed by St. Augustine[547] as that which "causes us to think of something beyond the impression the thing itself makes upon the senses"[548] regardless if the sign originates from nature or culture.[549] After Augustine, the Latin notion of the sign was further developed by great minds such as Boethius,[550] Aquinas,[551] Roger Bacon (1214-1292), Duns Scotus (1266-1308), William of Ockham (1285-1349), Domingo de Soto (1495-1569), Pedro da Fonseca (1528-1599), The Conimbricenses (1606, 1607).[552]

Yet, it was with John Poinsot (1589-1644) that the Latin development of semiotics finally reached maturity. In his *Treatise on Signs* (*Tractatus de Signis*),[553] Poinsot defines "the being proper to a sign" as "neither a transcendental nor a categorial nor a rational relation, but simply an ontological relation (a *relatio secundum esse*...)"[554] that is "triadic in character" because this

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[543] Deely, *Four Ages of Understanding*, 632.
[544] Deely, *Four Ages of Understanding*, 633. Emphasis mine.
[545] Deely, *Four Ages of Understanding*, 634.
[546] Deely, *Four Ages of Understanding*, 443.
[547] See Saint Augustine, *On Christian Doctrine*, trans. D. W. Robertson, JR (New Jersey: Prentice-Hall, Inc., 1958), Book I, Chapter 2.
[548] Augustine, *On Christian Doctrine*, 34.
[549] Deely, *Four Ages of Understanding*, 221.
[550] Deely, *Four Ages of Understanding*, 226.
[551] Thomas Aquinas, *Questiones Disputatae De Veritate*, trans. Robert W. Mulligan, S.J., James V. McGlynn, S.J., and Robert W. Schmidt, S.J. (Chicago: Henry Regnery Company, 1954), Q.9, A.4, ad, 4.
[552] Deely, *Four Ages of Understanding*, 331-430.
[553] John Deely, *Tractatus de Signis: the Semiotic of John Poinsot*; *In Bilingual Format* (Berkeley: University of California Press, 1985).
[554] Deely, *Four Ages of Understanding*, 430. See also: Deely, *Tractatus de Signis: the Semiotic of John Poinsot*, 119: "the rationale of a sign formally speaking does not consist in a relation according to the way being must be expressed in discourse [a transcendental relation], but in a relation according to the way relation has being [an ontological relation] (Ratio signi formaliter loquendo non consistit in relatione secundum dici, sed secundum esse)."

ontological sign relation "consists in the uniting or nexus of the three terms - sign-vehicle (that from which representation is made), interpretant (that to which representation is made), object-signified (that which is represented)."[555] From a Latin perspective, what is significant about the sign as an ontological relation is that it is "suprasubjective,"[556] that is, it is irreducible or indifferent to both the categorial or mind-independent relations[557] and the purely objective or mind-dependent relations[558] because an ontological relation can achieve that unification of the three terms, or "semiosis,"[559] proper to the being of a sign regardless of the status of these three terms, such as whether they consist of "a concept in the mind or ... a ... physical individual."[560]

This suprasubjective nature of the sign would be picked up by Charles Sanders Peirce hundreds of years later at the beginning of the Twentieth century, who brilliantly articulated that the interpretant within a triadic sign relation "need not be anything mental"[561] because:

> the essential function of a sign[vehicle] is to render inefficient relations efficient, - not to set them into action, but to establish a habit or general rule whereby they will act on occasion ... A sign [vehicle] therefore is an object which is in relation to its object on the one hand and to an interpretant on the other, in such a way as to bring the interpretant into a relation to the object, corresponding to its own relation to the object.[562]

In other words, the interpretant (in addition to the *sign-vehicle* or *representamen* and the *object* or *significate)* within a triadic sign relation does not need to be a conscious knower but can be anything that is brought "into a relation to the object" by this very sign relation because, as

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[555] Deely, *Four Ages of Understanding,* 433. See also Deely, *Tractatus de Signis: the Semiotic of John Poinsot*, 154/29-30: "...the single sign-relation, and this relation is the proper and formal rationale of the sign."
[556] Deely, *Four Ages of Understanding,* 433.
[557] Deely, *Four Ages of Understanding*, 229.
[558] Deely, *Four Ages of Understanding*, 229
[559] Deely, *Four Ages of Understanding*, 442.
[560] Deely, *Four Ages of Understanding*, 231.
[561] Deely, *Four Ages of Understanding*, 634.
[562] From *The Collected Papers of Charles Sanders Peirce*, Volume 8, paragraph 332 as referenced in Deely, *Four Ages of Understanding,* 634.

Morrissey (2017)[563] remarks via Deely (1990),[564] that what is essential to an interpretant is that "it be the ground upon which the sign [vehicle] is seen to be related to something else as signified."[565] The power of the actions of signs or semiosis as *extrinsic formal objective specificative causality*, therefore, is precisely to 'specify,' or give certain form to the interpretant, whether mental or physical, via the "intrinsic constitution of the sign-vehicle (in the case of a natural sign)"[566] so as to bring the interpretant "into a relation to the object."[567]

As such, the *extrinsic formal objective specificative cause* appears to be a suitable explanatory principle for the unity and systems-level properties and downward causation of the double-slit experiment according to the above discussion. Specifically, recall that for Bohm, the unity of the double-slit experiment is due to the quantum wave fields and the information they carry that are acting upon the particles as the quantum potential Q, since, according to Bohm and Hiley, the waves/fields are said to be going through both slits, and this interference with the slits causes the fields "to produce a complex quantum potential..[that exerts] a strong force on the particle,"[568] causing its wave-like behaviour.

Now, Bohm argues crucially that whilst the particles, in classical theories, "can be sources of fields," such as the "electromagnetic [fields]," the particles "do not serve as sources of the wave function"[569] in the quantum theory. Rather, the quantum wave fields and their function "can be 'seen' only through its manifestations in the motions of the particles."[570] This means that the quantum wave fields, on a Bohmian Interpretation, are not *internal* to the particles but are

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[563] Christopher S. Morrissey, "Analogy and the Semiotic Animal: Reading Marshall McLuhan with John Deely," *The American Journal of Semiotics* 32, no. 1/4 (2017): 51. https://philpapers.org/rec/MORAAT-29.

[564] Deely, *Basics of Semiotics (Advances In Semiotics)* (Bloomington: Indiana University Press, 1990).

[565] Deely, *Basics of Semiotics (Advances in semiotics)*, 26-27.

[566] Deely, *Four Ages of Understanding,* 634.

[567] From *The Collected Papers of Charles Sanders Peirce*, Volume 8, paragraph 332 as referenced in Deely, *Four Ages of Understanding,* 634.

[568] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 326-327.

[569] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336.

[570] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336.

external to them in origin, and they are thus only made known as they affect the behaviour of the particles as the quantum potential Q.

From an Aristotelian-Thomistic perspective, this means that the wave fields cannot be substantial forms, since substantial forms are intrinsic to the substances that exhibit them. Rather, the quantum wave field functions much more like an *extrinsic formal objective specificative cause* in that it precisely 'specifies' the particles with a certain form when it acts upon the particles as the quantum potential Q thereby bringing the particles, as the interpretant, "into a relation to the object,"[571] that, in this case, is the quantum wave field and the information it carries, which is signified by the quantum potential Q. As such, we have a distinct triadic sign relation within this Bohmian Interpretation of the double-slit experiment: the wave function/quantum potential Q is the *sign-vehicle* that is referring to a *significate/object*, which is the quantum wave field and its information that, as an *extrinsic formal objective specificative cause*, is giving form or specifying the *interpretant*(s), which are the particles being guided.

Moreover, these particles are indeed the kind of non-mental interpretants that Peirce recognized because the particles form precisely such a "ground upon which the sign [vehicle] is seen to be related to something else as signified,"[572] since the above discussed novel features, including wave-like behaviour, entangled state, and emergent holism, are not usually exhibited by 'particles' as such. These novel features hence become a **ground** upon which one may infer that their wave function, which describes these novel and unusual behaviors of the particles, may be a sign-vehicle signifying further guidance structure that is the field and its information.[573] The particles are thus the interpretants, "the ground on which an object [e.g., the wave

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[571] *The Collected Papers of Charles Sanders Peirce*, Volume 8, paragraph 332 as referenced in Deely, *Four Ages of Understanding,* 634.

[572] Deely, *Basics of Semiotics (Advances in semiotics),* 26-27.

[573] Recall Rizzi's interpretation that the quantum potential/wave function "contains information about the guidance of the particle (i.e. info about the guiding wave structure)."- Rizzi, *Physics for Realists: Quantum Mechanics*, 70.

function/quantum potential Q] functions as a sign [e.g., for the guiding structure]."[574]

What is interesting about this influence of the quantum wave fields upon particles from outside is that it nevertheless creates a degree of unity between the particles and its entire experimental environment during the double-slit experiment. This unity is enough to manifest some degree of downward-causation in that the fields, by weaving together all the information involved in the experiment as a whole, can alter the electrons and cause them to behave like waves, which seems to be a systems-level property which electrons cannot exhibit outside of the configuration of this whole experimental environment. As such, the double-slit experiment indeed exhibits wholeness, so much so that Bohr regarded it as indivisible even in thought.[575]

From Aristotelian-Thomistic and emergentist perspectives, however, the relationship between the quantum wave fields as *extrinsic formal objective specificative causes* and their corresponding particles within the double slit-experiment raises an interesting question: can non-substances, that is, *aggregates of things* without an unifying substantial form, also be *emergent entities* when they are organized by a suitable *extrinsic formal objective specificative cause*? The novel features of holism, downward causal power, and systems-level-properties of the double-slit experiment seems to suggest 'yes.' If this is true, however, this means that an Aristotelian-Thomistic analysis of emergence would not only include substantial forms, but also certain types of accidental forms, namely, those *extrinsic formal objective specificative causes* capable of causing some qualitatively meaningful degrees of unity (like that of the double-slit experiment), as real and meaningful formal causes of emergent entities even though their effect still falls short of the generation of substances. Moreover, this type of emergence by 'non-substantial' unity is also suggested by Tabaczek (2019), who proposes that one may characterize downward-

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[574] John Deely, Logic as a Liberal Art, [Loras College] Student Edition, Fall 1992. (Dubuque, IA: Letterheads to Books), 27.

[575] Bohm, *Causality and Chance In Modern Physics*, 89.

causation-based emergence "in reference to new substantial forms of more complex/higher entities ... and new accidental forms of more complex dynamical systems engaging particular entities ... The novelty of properties characteristic of emergent entities or dynamical systems finds its ground in the novelty of the substantial and accidental forms proper to them."[576]

As such, the Bohmian Interpretation of the double-slit experiment provides a concrete example of emergence, namely, the holistic double-slit experiment, in the quantum realm, which can be ontologically explained by and held in synthesis with the Aristotelian-Thomistic notion of **extrinsic formal objective-specificative cause**.

Section VI.2.: Quantum Entanglement:

Quantum entanglement is another suitable example that aptly illustrates the connection between the Bohmian Interpretation, emergentism, and Aristotelian-Thomism. Recall that quantum entanglement has been proposed by many, including Koons (2015, 2019), Rizzi, (2018), Ismael and Schaffer (2016), Hüttemann (2004), Kronz and Tiehen (2002), etc (see **Sections IV.5.2**, **IV. 5.3**, and **Section V.3**) as a candidate for wholeness and emergence because of its non-local connection between distant particles that is said to be caused by the holistic state of an entangled compound.[577] On this interpretation (see **Section V.3**), an entangled system is emergent because of its *holism-downward causal power* to organize its component particles to behave in a correlated state, which is a **novel** feature that the particles cannot exhibit except as part of this *entangled whole* that now exists as a qualitatively *new* and relatively *autonomous* phenomenon.

Recall that Bohm explains entanglement via a quantum wave field that functions as the

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[576] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 250.

[577] See, for example: Rizzi, *Physics for Realists: Quantum Mechanics*, 446. Maudlin, "Part and Whole in Quantum Mechanics," 56. Kronz and Tiehen, "Emergence and Quantum Mechanics,"343-344. Bohm, *Unfolding Meaning*, 7. Hüttemann, *What's Wrong With Microphysicalism?*47. Ismael and Schaffer, "Quantum Holism," 15.

quantum potential Q, which is a pool of common energy/information that in-forms and directs the kinetic energies of the entangled particles, such that if the kinetic energy of one particle changes, the other particle's energy changes simultaneously whilst the total kinetic energy of the two particles remains conserved, resulting in the anti-correlation of their spin states.[578] Similar to the double-slit experiment case, this Bohmian Interpretation of quantum entanglement too identifies a principle of unity, i.e., the holistic quantum wave field, that explains the true cause of an entangled system's wholeness and its ability to exercise downward causality upon its constituents.

Now, on an Aristotelian-Thomistic analysis, the role of the wave field of an entangled system seems analogous to the wave field of the double-slit experiment: like the latter, the former too functions as a *form*, or a principle of actuality that in-forms the behaviors of its particles by giving them a degree of unity or entangled-ness from the perspective of the whole, resulting in the correlated state. Moreover, given Bohm's position that the wave fields are external to the particles,[579] the wave field of an entangled system would likewise be an *extrinsic objective specificative form* to the entangled system, just as the wave field of a double-slit experiment is its respective *extrinsic objective specificative form*.

Interestingly, something similar to this formal cause-based interpretation of entanglement was recently proposed by Morganti (2021)[580], who holds that the Aristotelian-Hylomorphic idea of form is a "formal/functional/structural element that leads from a bunch of separate material constituents to a unitary whole with distinctive behaviour and properties."[581] Like many authors just pointed out above, Morganti too holds that the radical holism of quantum entanglement

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[578] Bohm and Hiley, *The Undivided Universe*, 36.
[579] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336.
[580] I would like to thank Professor Morganti for generously sharing this paper with me.
[581] Matteo Morganti, "Quantum Entanglement: A Hylomorphic Account," *Synthese* 198, no. 11 (2021): 1. https://link.springer.com/article/10.1007/s11229-019-02280-z.

suggest that "a reductive account is not going to work. Whatever their correct ontological interpretation...entangled quantum systems will have to be conceived as more than just sums, or collections, of objects with monadic properties."[582] This disposition leads Morganti to argue that "entangled physical systems are constituted by objects and monadic properties...but are at the same time characterised by a structural element which is responsible for the fact that the entangled parts exhibit *correlated* values...*upon measurement*."[583] Therefore, Morganti argues that "entanglement can be understood, and perhaps is best understood, in the hylomorphic sense of composite systems constituted by material parts (i.e., particles) plus a sui generis structural element,"[584] or form, which, as the cause for the "peculiar features of the composite," is nevertheless "not reducible in any straightforward way to those of the components."[585]

On Morganti's account, one major advantage with adopting a hylomorphic interpretation of quantum entanglement is that it helps us to understand the 'origin' of entangled systems. Although entanglement is often described in terms of interaction, interaction is "*neither sufficient nor necessary for entanglement*"[586] because not all interactions are 'entangled interactions', and in cases like "entanglement swapping,"[587] entanglement can even be created without interaction. Instead, Morganti suggests that entanglement is best understood relationally as "irreducible correlations...encoded in the entangled system's wave-function."[588] These 'irreducible correlations' thus appear to be the true origin and *cause* of the correlated behaviour of the

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[582] Morganti, "Quantum Entanglement: A Hylomorphic Account," 5.
[583] Morganti, "Quantum Entanglement: A Hylomorphic Account," 2.
[584] Morganti, "Quantum Entanglement: A Hylomorphic Account," 8.
[585] Morganti, "Quantum Entanglement: A Hylomorphic Account," 8-9.
[586] Morganti, "Quantum Entanglement: A Hylomorphic Account," 10.
[587] "Entanglement swapping occurs when, for instance, four particles are entangled pairwise (say, particle 1 is entangled with particle 2 and particle 3 is entangled with particle 4), and one acts in specific ways on the two systems, e.g., performing a joint measurement on the 'shared pair' constituted by 2 and 3. If this is done, strikingly, 1 and 4 become entangled even if they strictly speaking never encountered each other: they were not previously bonded by a force, nor did they change their relative states because of a force acting on the two of them—be it simultaneously or at different times" - Morganti, "Quantum Entanglement: A Hylomorphic Account," 10.
[588] Morganti, "Quantum Entanglement: A Hylomorphic Account," 10.

entangled particles as an *effect*. Importantly, Morganti suggests that his hylomorphic interpretation is compatible with a Bohmian Interpretation: "...the way in which Bohmian particles are interconnected could be understood in terms of form/structure, as per hylomorphism...depending on one's particular take on the ontological status of the wave-function in Bohmian mechanics, a particular form of hylomorphism would follow."[589]

And what "particular form of hylomorphism" could it be, in the case of quantum entanglement, if not the Bohmian framework that entangled particles, as matter, are interconnected by a quantum wave field that, as a common pool of active information, directs the particles as an extrinsic exemplary form[590] that is the source of their 'irreducible correlations'!

As such, Morganti's hylomorphic analysis and interpretation of entanglement highlights forms as the true cause of its emergent wholeness, and the Bohmian Interpretation yet again supplies evidential supports to this connection between Aristotelian-Thomistic metaphysics and emergentism, illustrating vividly Morganti's Aristotelian-hylomorphic claim that forms "turn out to make a difference already in the case of (certain) physical composites, making them in a clear way irreducible to their parts," making the "typical reductionist view...even less plausible than it already is."[591]

Section VI.3: The Nature of the Bohmian Information.

Moreover, a foundational concept of the Bohmian Interpretation that is essential to the

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[589] Morganti, "Quantum Entanglement: A Hylomorphic Account," 16.

[590] "Because there is nothing to push against we should not regard the **quantum potential as giving rise to an efficient cause, ('pushing and pulling') but it should be regarded more in the spirit of providing an example of Aristotle's formative cause.** That is the quantum potential gives new form to the evolution of the trajectories, in a way that is very reminiscent of the morphogenetic fields proposed by Waddington (1956) and Thom (1975) in biology.**The form is provided from within** but it is, of course, shaped by the environment. Thus the quantum potential reflects the experimental conditions. Close one slit and the quantum potential changes and the subsequent evolution of the particle is different. **There seems to be a kind of 'self-organisation' involved**." - B. J. Hiley, "From the Heisenberg Picture to Bohm: A New Perspective On Active Information and Its Relation To Shannon Information," in *Quantum Theory: Reconsideration of Foundations*, ed. A. Khrennikov (Växjö: Växjö University Press , 2002), (17) 141-162. Emphasis mine.

[591] Morganti, "Quantum Entanglement: A Hylomorphic Account,"20.

proceeding discussions, i.e., Bohm's notion of information, needs to be clarified.

As illustrated above, one of the most noteworthy features of the Bohmian Interpretation is its ability to recognize qualitatively genuine wholeness in nature and distinguish them from mere quantitative 'aggregates' or heaps of matter. The crucial notion with which Bohm distinguishes between wholeness and heap is *information*: genuine 'wholes' exhibit wholeness because they are said to be "guided by a pool of common information,"[592] and heaps are mere aggregates without genuine wholeness because they are "constituted of independent parts guided by separate pools of information."[593] What, then, is information for Bohm?

Bohm suggested some preliminary answers to this question: as discussed earlier in **Section IV. 5.3**, information/active information for Bohm means quite literately that which 'in-forms,' or to "actively...put form into something or to imbue something with form."[594] [595] Active information is described by Bohm & Hiley as "a **form** having very little energy [that] enters into and directs a much greater energy. The activity of the latter is in this way given a **form** similar to that of the smaller energy."[596] At first glance, these texts might suggest that 'information' is just a description of the functional role of any form of energy as it acts upon another energy thereby informing or directing it. However, an important clarification is made by Bohm, Hiley, and

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[592] Bohm and Hiley, *The Undivided Universe*, 61.

[593] Bohm and Hiley, *The Undivided Universe*, 61.

[594] Bohm and Hiley, *The Undivided Universe*, 35.

[595] "Now **self-organisation** requires the notion of information to be **active** ... In a quantum system I want to suggest that the information is provided by the experimental conditions, its environment. But this **information is not passive. It is active and causes the internal energy to be redistributed** between the kinetic (pB) and potential (Q) parts. Thus the quantum process is literally '**formed from within**'. Notice I am not using the notion of information in its usual sense but following its meaning **in a literal sense**. As Miller (1987) points out, **the etymological origins of the word 'information' stresses the active role of information. In-form literally means to form from with in.** He writes, "The central stem ({\em forma}) carries **the primary meaning of visible form**, outward appearance, shape or outline. So ***informare* signifies the action of forming, fashioning or bringing a certain shape or order into something." So when I use the word information here, I do not mean information for me, the experimenter, but the activity taking place in the system itself**. In other words information is playing an objective and active role in all quantum processes." - Hiley, "From the Heisenberg Picture to Bohm," (17-18)141-162. Emphasis mine.

[596] Bohm and Hiley, *The Undivided Universe*, 35.

Kaloyerou (1987):

> In other applications of information theory, there has always been some material system or field that carries the information. This implies that such information has a certain usually small energy, but that the energy in the activity which is its "meaning" is much larger and has an **independent source**.[597]

Hence, just as the quantum wave fields are external to their corresponding particles, information is also external to or "has an independent source" apart from the wave fields. The fields, as a form of energy, are thus the 'carrier' of information, and it is ultimately by this information that the fields direct the particles.

As we have seen, these notions of information and wave fields enable Bohm to explain quantum wholeness as the result of the workings (the quantum potential Q) of the quantum wave fields[598] that in-form or direct the particles according to the information that they carry. When certain information and its corresponding fields are directing multiple particles in a unitary way, the information is thus vividly described by Bohm as 'pools of common information,'[599] as they are shared by many entities, directing them to participate in a common "dance."[600] The holisms of double-slit experiment and quantum entanglement are precisely examples of systems being guided by one common pool of information: as we have seen that in both of these cases, it is one single quantum wave field that, with its information, weaves all elements of their respective phenomenon together into an undivided wholeness. A pool of common information thus amounts to the workings (the quantum potential Q) of one quantum wave field that can direct many elements of the quantum world together, making them behave or 'dance' in a unified way

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[597] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336. Emphasis added.
[598] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 325.
[599] Bohm and Peat, *Science, Order, and Creativity*, 193.
[600] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 334.

according to the information that it carries as an *extrinsic formal objective specificative cause*.[601] Moreover, the Bohmian information differs significantly from the notion of Shannon information that is the subject of Information and communication theory. As Seager (2018) points out, Shannon information is 'for us,' which means it is not *intrinsically* meaningful or semantic; rather, it is a "string of bits"[602] that requires human interpretation. Conversely, the Bohmian information is "intrinsically semantic"[603] because it is "for the particle and therefore measures some form of objective information"[604] even apart from human interpretation.[605]

More questions can still be raised toward the Bohmian information, however, such as its precise origin and nature, etc. As Seager (2018) suggests, "It must be admitted that the concept [information] is not without some obscurity," since: "it is unclear how exactly active information operates in the world...whether it is simply another operative causal feature...another aspect of the relational structure of the empirical world, or whether it is something deeper which is involved in the structuring itself."[606]

As Bohm, Hiley, Kaloyerou (1987) admit that, so far, "we have no theory as to what is the origin of the quantum potential...we may suppose that the information it represents is carried in some much more subtle level of matter and energy, which has not yet manifested in physical

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[601] "Most dramatically **form appears in the guise of the wave function**. It is the global form of the wave function (symmetric or antisymmetric) that is responsible for the existence of Fermi-Dirac or Bose-Einstein statistics. The fact that such forms are non-factorizable (into spatially independent components) is the deep reason for quantum non-locality (Bell's mysterious correlation between distant particles). The form of the wave function is ultimately responsible for collective modes in physics - plasma, superfluid, superconductor and hypothetical Frochlich systems. The **form of the wave function orchestrates each of an astronomical number of particles into a highly coordinated dance. Bohm's quantum potential is unique in that the magnitude of its effects, on the motion of electrons, does not arise from its strength or intensity but from the "form" of the potential** - that is, its particular complex shape. It is for this reason that the effects of the quantum potential do no fall off with distance and that **well separated quantum objects can remain strongly correlated." -** F. David. Peat, "Active Information, Meaning and Form," *Frontier Perspectives* 8 (1999): 49-53. Emphasis added. https://www.fdavidpeat.com/bibliography/essays/fzmean.htm.

[602] William Seager, "The Philosophical and Scientific Metaphysics of David Bohm," *Entropy* 20, no. 7 (2018): 8. https://www.mdpi.com/1099-4300/20/7/493

[603] Seager, "The Philosophical and Scientific Metaphysics of David Bohm," 8.

[604] Hiley, "From the Heisenberg Picture to Bohm," (21) 141-162.

[605] Hiley, "From the Heisenberg Picture to Bohm," (17-18) 141-162.

[606] Seager, "The Philosophical and Scientific Metaphysics of David Bohm," 8.

research."[607] Nevertheless, they suggest that the origin of information could be sought in the ever more complex and subtle structure of the particles "as we go to smaller low dimensions."[608] Thus, the Bohmian information remains an unfinished research project that could very well be a pathway to further development in our scientific understanding of the physical universe: as Peat (1999) proposes, information might be regarded as "a new physical concept, one that can be placed alongside Matter and Energy."[609] Seager (2018) likewise suggests that information might be "something deeper which is involved in the structuring [of the empirical world] itself" akin to Aristotle's notion of " "form" [which is] structural features of the world: the pattern of interaction and system of spatial-temporal relations described in physical theory."[610]

Section VI.4: The Implicate Order.

Philosophically, however, we may explore further the ontological significance of the Bohmian information, which brings us to Bohm's proprietary notion of the implicate order. From a Bohmian perspective, the notion of 'order' signifies our fundamental conception of a given aspect/layer of reality, and sometimes reality as a whole. For example, the "new secular order"[611] that has dominated the West after the Middle Ages is characterized by an "atomistic" understanding of the universe as "an immense and purposeless mechanical universe" describable via Descartes' "grids" and "coordinates."[612] Within this grid universe, the most basic and manifested reality is "separate objects moving on trajectories...described in terms of Cartesian coordinates."[613] Bohm terms this atomistic-mechanical conception of the universe "the explicate

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[607] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336.
[608] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336.
[609] Peat, "Active Information, Meaning and Form," 49-53. Emphasis added.
[610] Seager, "The Philosophical and Scientific Metaphysics of David Bohm," 8.
[611] Bohm and Peat, *Science, Order, and Creativity*, 106.
[612] Bohm and Peat, *Science, Order, and Creativity*, 107.
[613] Bohm and Peat, *Science, Order, and Creativity*, 174.

order."[614] Yet, as explicated at length above in **Section IV**, our conception of physics and the physical world had gone through revolutionary changes since the seventeenth century, and one of the consequences of these changes is that "the notions of particle and trajectory have ceased to be basic"[615] because they are now often viewed as the results of deeper underlying factors and phenomena, such as the behaviour of fields, information, etc.

Thus, Bohm and Peat (1987) suggest that the supremacy of the atomistic worldview is the 'left over' of an no longer adequate "old older."[616] Instead, Bohm proposes a new worldview: "The implicate or enfolded order,"[617] which is defined by "the simultaneous presence of a sequence of many degrees of enfoldment with similar differences between them...Such an order cannot be made explicit as a whole, but can be manifested only in the emergence of successive degrees of enfoldment."[618] For instance, the movement and trajectories of particles (the explicate order), are only made manifested or unfolded in the quantum context by the quantum wave fields that underlie them. The wave fields and their information thus constitute an 'implicate order' beneath the particles as a deeper 'layer' of reality. Furthermore, the implicate order is capable of being extended to incorporate quantum field theory: in this case, the particles are seen as "quantized excitations"[619] of the quantum wave fields, which can be described as being "acted on by a superquantum potential...far subtler and more complex than the quantum potential."[620] The superquantum potential thus constitutes a "*second implicate order*"[621] or super-implicate order

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[614] Bohm and Peat, *Science, Order, and Creativity*, 174.
[615] Bohm and Peat, *Science, Order, and Creativity*, 174.
[616] Bohm and Peat, *Science, Order, and Creativity*, 174.
[617] Bohm and Peat, *Science, Order, and Creativity*, 172.
[618] Bohm and Peat, *Science, Order, and Creativity*, 174.
[619] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 350. For a presentation of the Bohmian Interpretation of quantum field theory, see Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory,"349-375.
[620] Bohm and Peat, *Science, Order, and Creativity*, 182.
[621] Bohm and Peat, *Science, Order, and Creativity*, 182.

that, with its "information,"[622] "guides and organizes [the] original field"[623] of the first implicate order to produce particlelike structures that constituent the explicate order.

Bohm and Peat (1987) illustrates the relationship between the explicate, the implicate, and the superimplicate orders with the following example: the explicate order is like a television *screen* that can only show certain images when informed by, for instance, a *computer*, the first implicate order, "which supplies the information that arranges"[624] the screen to show certain images. The first implicate order's information, however, is supplied by a yet deeper second implicate order like a *person* who is programming the computer and the screen. Moreover, Bohm and Hiley (1993) propose that there can be an indefinitely many "higher levels of implicate order...each is related to the one below, as the one below is related to the one still further below."[625] The cosmos is thus "an order of implicate orders"[626] in which the explicate order of mechanical atomism is only the surface.

Section VI.5: Synthesis: Putting It All Together

Now, from Aristotelian-Thomistic and emergentists perspectives, profound congruities are present in Bohm's universe of implicate orders.

Bohm, Emergence, and The Aristotelian Pluralistic Ontology:

To begin, the Bohmian universe of the implicate orders is "generative"[627] because it can give rise to many distinct kinds of beings, which coincides with **the Aristotelian-Thomistic and emergentist claims that there are irreducibly distinct *kinds* of emergent existence**, including certain 'wholes' consisting of substantial or accidental forms, which contradicts the atomistic-mechanical worldview that all existence is different arrangements of the same kind of existence,

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[622] Bohm and Peat, *Science, Order, and Creativity*, 183.
[623] Bohm and Peat, *Science, Order, and Creativity*, 183.
[624] Bohm and Peat, *Science, Order, and Creativity*, 183.
[625] Bohm and Hiley, *The Undivided Universe*, 380.
[626] Bohm and Hiley, *The Undivided Universe*, 380.
[627] Bohm and Peat, *Science, Order, and Creativity*, 151.

i.e., the fundamental particles. Specifically, a "*generative order*"[628] is "a deeper and more inward order out of which the manifest form of things can emerge creatively"[629] because this order has the "potentiality" to cause "a kind of whole [to be] generated from certain basic principles."[630] The double-slit experiment and entanglement are precisely examples of such generated and emergent 'wholes' since they consist of particles being organized by fields and common pools of information from the first and second implicate orders, which have thus 'generated' these 'wholes' as they unfold or actualize the potentialities of the particles to participate in these 'wholes'. These holistic phenomena are thus emergent on account of the information that make them 'one,' which is from the implicate order and not the interaction of their pre-existing (explicate) parts. Moreover, in the context of the quantum field theory, all of the so-called particles, including elementary particles and perhaps even some "higher-level entities, such as atoms and molecules,"[631]can be explained via the implicate orders as distinct *kinds of* excitations of the quantum wave field (the first implicate order) generated by the super-quantum potential and information from the second or super implicate order[632] (and possibly beyond) as they act upon the first implicate order. Hence, just as Aristotle's pluralistic ontology recognizes many cases of being, Bohm too views the cosmos as filled with many qualitatively distinct entities springing forth from the deep generative interaction between the explicate and implicate orders, which, metaphysically speaking, accomplishes **a retrieval of the Aristotelian-Thomistic view that physical entities are compositions between potentiality and actuality**.

Bohm and Hylomorphism:

As discussed above in **Section II and V**, unlike the atomistic-mechanical view that the

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[628] Bohm and Peat, *Science, Order, and Creativity*, 151.
[629] Bohm and Peat, *Science, Order, and Creativity*, 172.
[630] Bohm and Peat, *Science, Order, and Creativity*, 172.
[631] Bohm and Peat, *Science, Order, and Creativity*, 193.
[632] Bohm and Peat, *Science, Order, and Creativity*, 193.

universe is reducible to basic simple entities that are 'givens,' Aristotelian-Thomistic metaphysics views physical entities as composites of two fundamental principles: potency and act, that function, respectively, as their matter and form. Interestingly, this hylomorphic ontology' is also found in Bohm to the degree that in his view, physical entities are "relatively constant and autonomous particlelike"[633] structures that arise from the organization or in-form-mation of the implicate orders upon the explicate order. This can perhaps be most clearly seen in Bohm's interpretation of the quantum field theory: in this case, the particles would consist of the energy supplied by the quantum field of the first implicate order, which, in Aristotelian terms, is a kind of matter that can be actualized by a principle of actuality, which, in Bohm's terms, is the superquantum potential and information from the second implicate order that 'gives form' to the energy of the first implicate order, generating the particlelike structures.

The Bohmian information thus resembles the Aristotelian-Thomistic form since it is an instance of actuality that actualizes matter or energy's potentiality to take on relatively stable formal structures. In fact, one may boldly propose that Bohm's 'information' is a physical description or name for the Aristotelian 'form' because the Bohmian information seems to have a quite broad meaning that includes any instance of actuality that in-forms, or actualizes potentiality or matter/energy. As such, Bohm's information may be understood as an analogical name for form as a principle of actuality in its actualizing-relation to matter in the physical world, and this interpretation is already foreshadowed by David Peat's proposal that information should be understood as "a new physical concept, one that can be placed alongside Matter and Energy,"[634] or Seager's proposal that Bohm's information might be "something deeper which is involved in the structuring [of the empirical world] itself" akin to Aristotle's notion of " 'form'

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[633] Bohm and Peat, *Science, Order, and Creativity*, 193.
[634] Peat, "Active Information, Meaning and Form," 49-53.

[which is] structural features of the world: the pattern of interaction and system of spatial-temporal relations described in physical theory."[635] Indeed, from a hylomorphic standpoint, if matter/energy signify a physical understanding of *potentiality*, it is only appropriate that they are accompanied by 'information' that may signify a physical understanding of *actuality* as form, which gave matter/energy their relatively stable and recognizable organizations in the first place.

Interestingly, Hiley (2002) too explores the possibility of interpreting Bohm's information as the Aristotelian form. Hiley clarifies a prior presentation[636] of the Bohmian Interpretation by asserting that "There are some problems" with the view that the quantum potential is simply "a [external] field of energy...producing a force on the particle."[637] Instead, Hiley argues that the quantum potential's energy and information, when informing particles, become "internal"[638] to them. Hence, Hiley states that the quantum potential should not be viewed as "giving rise to an efficient cause, ('pushing and pulling') but it should be regarded more in the spirit of providing an example of Aristotle's formative cause...[that] gives new *form* to the evolution of the trajectories."[639] In other words, the quantum potential and the "active...information"[640] it contains, for Hiley, goes 'into' the entities that they inform, causing their "quantum process...[to be] 'formed from within.' "[641] Hiley's description of information as '*internal*' to the entities/energy that it informs is significant, from Aristotelian-Thomistic and emergentist perspectives, for two reasons.

Firstly, it enhances the point that information and its carriers, i.e., the quantum and

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[635] Seager, "The Philosophical and Scientific Metaphysics of David Bohm," 8.

[636] For example, Bohm and Hiley (1987) "The main difference is that the particles can be sources of fields, whereas, in the quantum theory, particles do not serve as sources of the wave function. But evidently this does not affect the question of how the fields are manifest themselves."- Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," An Ontological Basis for the Quantum Theory,"336.

[637] Hiley, "From the Heisenberg Picture to Bohm," (16) 141-162 .

[638] Hiley, "From the Heisenberg Picture to Bohm," (16) 141-162 .

[639] Hiley, "From the Heisenberg Picture to Bohm," (17) 141-162 .

[640] Hiley, "From the Heisenberg Picture to Bohm," (17) 141-162 .

[641] Hiley, "From the Heisenberg Picture to Bohm," (17) 141-162 .

superquantum potentials, function truly like the Aristotelian (accidental) formal, rather than the efficient, cause, and as discussed above in sections **VI.1 &2,** that this is quite apparent in the cases of the double-slit experiment and quantum entanglement where the quantum potential Q and its information function as *accidental extrinsic objective specificative forms* of those phenomena, making them emergent 'wholes' by in-forming their constituents to behave in an irreducibly unitary way. As such, the Bohmian Interpretation gives a straightforward support, on physical grounds, to the conception of emergence and downward causation via not efficient causation but formal causation argued for by Stump and Tabaczek[642] since in the Bohmian view, emergence is the result of not the efficient but formal causation of the quantum potential Q as it informs certain physical systems downwardly and holistically.

Secondly, an 'intrinsic' understanding of information also opens the possibility of interpreting certain information as *intrinsic principles* of actuality that make certain 'wholes' genuine Aristotelian substances; these said principles are, of course, the **substantial forms**. For example, recall Bohm and Hiley (1993) argue that the hydrogen atom is a case of quantum wholeness (**Section IV.5.3)** because the atom's quantum potential Q, which is interpreted by Bohm and Hiley as a many-body wave function that "is said to determine the quantum state"[643] of the hydrogen atom, including all of its constituents like its electron and proton, from the perspective of the atom as a whole.

To use the language of emergentism, the hydrogen atom is thus an emergent entity because it exhibits a kind of holism-downward causation by virtue of its ability to determine the state of its constituents via the many-body wave function that is proper to the hydrogen atom as a

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[642] Mariusz Tabaczek, "Emergence and Downward Causation Reconsidered In Terms of the Aristotelian-Thomistic View of Causation and Divine Action," *Scientia et Fides* 4, no. 1 (2016): 115-149 https://apcz.umk.pl/SetF/article/view/SetF.2016.010.

[643] Bohm and Hiley, *The Undivided Universe*, 58.

whole, which would result in systems-level properties and causal powers that the constituents of the hydrogen atom cannot have except as components of the hydrogen atom. For instance, Tabaczek points out that an electron in a hydrogen atom has the ability to form "a covalent bond" with the electron of another hydrogen atom to form a hydrogen molecule, which is an ability that the electron "did not possess before becoming "a part"[644] of the hydrogen atom.

As such, Tabaczek argues that "metaphysically speaking, we are not dealing with an electron anymore, but a hydrogen atom in which the electron in question is present virtually (by power), and not actually,"[645] such that "the hydrogen atom possesses the power of forming a covalent bond "through" an electron virtually present in it."[646] As such, the hydrogen atom seems to be a characteristically Aristotelian substance exhibiting a principle of substantial unity, that is, its substantial form by virtue of its ability to alter the features of its parts[647], giving them qualitatively or irreducibly new features[648] from the standpoint of the hydrogen atom holistically.

Yet, Bohm and Hiley (1993) seem to identify the hydrogen atom's principle of unity precisely with the pool of common information carried by its quantum potential Q that binds the hydrogen atom together, giving it its unity and wholeness.[649] Is the substantial form of the hydrogen atom, then, its 'pool of common (Bohmian) information,' contained in its quantum potential Q, that is making the hydrogen atom a unified substance? Given Hiley's (2002) description that information and quantum potential "should be regarded more in the spirit of providing an example of Aristotle's formative cause"[650] as an in-forming agent "internal"[651] to what it informs (i.e., the hydrogen atom), the answer seems to be 'yes,' because as it is described

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[644] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 225.
[645] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 340.
[646] Tabaczek, *Emergence: Towards A New Metaphysics And Philosophy of Science*, 225.
[647] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 3, 779, p.287.
[648] Feser, Scholastic Metaphysics, 168.
[649] Bohm and Hiley, *The Undivided Universe*, 58-59.
[650] Hiley, "From the Heisenberg Picture to Bohm," (17) 141-162 .
[651] Hiley, "From the Heisenberg Picture to Bohm," (16) 141-162 .

by Hiley, the Bohmian information bears remarkable resemblance with the Aristotelian-Thomistic substantial form that is an intrinsic principle of actuality, which, as the essence of a substance,[652] "confers causal powers on the whole"[653] substance, giving it its unified existence and irreducibly holistic features.

However, the suggested equivalence between Bohm's information and the Aristotelian-Thomistic substantial form may be difficult to affirm or deny with certainty at present, given Bohm & Hiley[654], and Peat's[655] recognition that so far, we do not have sufficient knowledge regarding the origin and precise nature of information. It could be that information, as David Peat and Seager[656] proposed, turned out to be another fundamental factor in the physical world, in which case information may be understood as an analogical name for the Aristotelian-Thomistic form as an instance of actuality manifested in the physical realm in an actualizing-relation to matter. It could also be that information corresponds with something concrete and physical, in which case it might be understood as a specific instance of the Aristotelian-Thomistic form as it actualizes certain matter/energy. Only time will tell. Regardless of these uncertainties, however, the utilization of the Aristotelian-Thomistic form and hylomorphism as a whole by the Bohmian Interpretation constitutes a significant support to, and retrieval of, the Aristotelian-Thomistic metaphysics on physical ground, demonstrating its remarkable explanatory power and applicability even in the context of contemporary and possibility future quantum theory.

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[652] "Et alio modo dicitur substantia quod **quid** erat esse, quod pertinet ad formam." - Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lessons 7, 1566, p.616. Emphasis added.

[653] Stump, "Emergence, Causal Powers," 53.

[654] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 336.

[655] "The actual nature of the information and the way it is carried is not yet entirely clear. Is it really correct, for example, to speak of a "field" of information, since information does not fall off with distance, neither is it associated with energy in the usual sense. Possibly the notion of field should be widened or, at the quantum level. we should be talking about pre-space structures, or about algebraic relationships that precede the structure of space and time." - Peat, "Active Information, Meaning and Form," 49-53.

[656] Seager, "The Philosophical and Scientific Metaphysics of David Bohm," 8.

Bohm and Aristotle's Many Senses of Being: the Causes and the Categories.

If the Bohmian world of implicate orders indeed retrieves the Aristotelian-Thomistic metaphysics of potency & act and form & matter, this entails that the Bohmian Interpretation also affirms other key features of the Aristotelian-Thomistic worldview, and the first of which is the classical Aristotelian pluralistic view of being. As discussed in **Section V.5.1**, Aristotle held that being is said in many ways via (at least) the categories and potentiality & actuality. The Bohmian framework vindicates this Aristotelian pluralistic ontology in the physical realm: in this case, the matter/energy of the implicate orders amounts to potentialities that can be acted upon by the actualities of the implicate orders, i.e.,the quantum and superquantum potentials and the information that they carry. This distinction between potential-being and actual-being further enables Bohm to account for the existence of many qualitatively distinct kinds of things, such as the elementary particles and 'wholes' discussed above, as resulting from differing pools of information (or form) that 'inform' energy to be this or that *kind* of concrete physical things that are precisely the subject of description of the Aristotelian-Scholastic causes and categories, including both real quantities and qualities.[657]

Bohm and the Principle of Causality:

The Bohmian recognition of potentiality and actuality as distinct instances of being also enables Bohm to affirm the Aristotelian **principle of causality**, the view that change is the result of the reduction of "potentiality to actuality...by something in a state of actuality."[658] Indeed, it is quite transparent that for Bohm, physical phenomena (such as the wave-like behaviour of particles in double-slit experiment) are the result of real causes actualizing real potentialities, (such as the quantum wave field that act upon the particles to direct them). As such, physical

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[657] Bohm, *Causality and Chance In Modern Physics*, 52-54. See also this essay, Section II.
[658] Aquinas, *Summa Theologiae*, I, q.2, a.3.

phenomena are intelligible for Bohm precisely because they are 'caused' by the interaction of potency and act as real features of the world, and this affirmation of the principle of causality is the whole reason why Bohm entitled his approach to physics a "causal interpretation."[659] As such, Bohm in fact stands in continuity with the whole Aristotelian-Scholastic tradition that understands science as a *causal analysis* of being, and scientific knowledge the *causal knowledge* of the "true, immediate, and proper"[660] causes of things.

Bohm's causal/ontological Interpretation of physics thus amounts to a radical 'quantum' retrieval of the Aristotelian-Scholastic understanding of science as natural philosophy in the context of quantum physics for the sake of preserving the very possibility of science as real and concrete causal knowledge of the physical world over against the whole modern-mechanistic Western tradition that undermines the very ontological foundation of scientific knowledge. For the mechanistic treatment of science reduces it to a search for the useful via its treatment of causation as 'necessary connection,' which, as Locke points out, puts the "scientifical...still...out of our reach,"[661] causing Hume to famously conclude that the physical world is 'loose and separate.' This modern mechanical conception of science and causation has ultimately led to a despair toward scientific knowledge famously expressed by Niels Bohr that quantum phenomena are "arbitrary and lawless."[662] By retrieving the Aristotelian conception of science as knowledge of real causes through proposing the Causal/ontological Interpretation, however, Bohm radically rejects the whole modern philosophical conception of causation and argues for a foundation of scientific knowledge on causal ground via Aristotelianism.

Section VI.6: Summary and Conclusion.

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[659] Bohm, *Causality and Chance In Modern Physics*, 52-54.
[660] Weisheipl, *Aristotelian Methodology.*
[661] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 26.
[662] Bohm, *Causality and Chance In Modern Physics*, 89.

This section is devoted to a synthesis between Bohm, Emergence, and Aristotelian-Thomistic metaphysics for the purpose of illustrating that the Bohmian causal/ontological interpretation of physics provides concrete evidence for the claims of emergentism and Aristotelian-Thomistic metaphysics that there exist irreducibly emergent entities in nature.

This illustrative synthesis has been developed through, **firstly**, arguing in **Section VI.1** that the Bohmian information carried by quantum wave fields constitutes an Aristotelian-Scholastic extrinsic exemplary form that causes and explains the emergent status of an double-slit experiment; **secondly**, arguing in **Section VI.2** that the pool of common Bohmian information of an entangled quantum system is likewise an Aristotelian-Scholastic extrinsic exemplary form responsible for the emergent status of the entangled system; **thirdly**, suggesting in **Section VI.3** that the Bohmian information resembles significantly the Aristotelian-Thomistic notion of form; **fourthly**, arguing in **Section VI.4-5** that Bohm's proprietary notion of the implicate order aptly explains the origin of emergence and retrieves the Aristotelian pluralistic ontology, Hylomorphism, many senses of being, and the principle of causality.

If not mistaken, this synthesis of Bohm, Emergentism, and Aristotelian-Thomism constitutes, in Gerald Holton's terms, an update of the **z-axis** *or themata* of science, which is the fundamental ontological worldview[663] with which we understand and interpret science, to be in sync with the **x-axis** (the experimental and empirical aspects) and **y-axis** (the mathematical and theoretical aspects) of contemporary science. This update in turn allows the **z-axis o**f science to move beyond the modern atomistic-mechanical reductionism to a 'post-modern' holistic approach that suitably acknowledges wholeness and emergence in nature as they are discovered by science and robustly articulated via an Aristotelian-Thomistic

[663] Including "the fundamental presuppositions, methodological judgments and decisions, philosophical convictions, ideological and even theological views" within the context of which the findings of science are often interpreted and understood." - Wallace, *Causality and Scientific Explanation*, *Vol.II*, 241.

metaphysics. Evidently, such a fundamental shift of worldview yields implications on how one views many other aspects of life, including ethics, the environment, the human person, society, religion, etc. This essay will explore some of these potential implications in section **VIII** after a consideration of some potential objections in Section **VII.**

VII: Responding to Objections.

VII.1.: Objections Against A Holism-Based ('Synchronic') Approach to Emergence From Humphreys' 'Diachronic' Approach To Emergence.

The holism-based approach to emergence that this essay argues for was critiqued by Humphreys (2016), who argues that a **synchronic approach to emergence**, the idea that "emergence occurs when a relation imposes synchronic structure on a collection of entities and novelty appears as a consequence," is "ill-suited to the task of understanding of emergence"[664] via two major objections: **(1)** "Holism is insufficient for emergence because holistic properties can be possessed by systems that do not display emergent features," for example, "The number of objects in a finite collection of discrete entities is a property of the entire collection, rather than of the individuals that compose it, but this is no emergent property."[665] **(2)** Emergence is best understood "diachronically"[666] as the transformations between fundamental entities, which make "transformational emergence essentially different from generative atomism, in which the fundamental entities are immutable."[667] For an example of diachronic emergence, consider the Standard Model of particle physics, which recognizes, amongst others, six types of **leptons**: electrons/electron neutrinos, muons/muon neutrinos, and tauons/tauon neutrinos. Humphreys argues that the leptons are considered 'fundamental' because they "have no components, "no

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[664] Humphreys, *Emergence: A Philosophical Account*, 130-131.
[665] Humphreys, *Emergence: A Philosophical Account*, 37.
[666] Humphreys, *Emergence: A Philosophical Account*, 135.
[667] Humphreys, *Emergence: A Philosophical Account*, 60.

internal structure," and "are not composed of quarks."[668] For Humphreys, therefore, when leptons transform, e.g., a muon decaying into an electron, a neutrino, and an antineutrino, no part-whole analysis is applicable to these cases of transformational emergence because they do not consist in "decomposition of a lepton into its constituents, of which it has none."[669] Rather, the transformational emergence of an electron, etc., from a muon, is 'diachronic' or a case of one 'simple' entity becoming another without any synchronic emergence or holism at play.[670]

Replies: To **objection (1)** I answer that this objection arises from an ambiguity between the many senses or degrees of 'holism'. To begin, wholeness or holism is defined by Aristotle in the *Metaphysics*, Book Ten as a type of *oneness*[671] resulting from "some form or specifying principle"[672] applied unto a thing or a collection of things. Crucially, Aristotle suggests that holism comes in *degrees*, and the "greatest degree"[673] of holism is achieved intrinsically by a nature or, in Aquinas' designation, a **substantial form**.[674] A weaker degree of holism can still occur, however, when a form is imposed upon things "by force,"[675] which suggests that the said form is a kind of accidental form or **extrinsic objective specificative forms** discussed above.

With (at least) these two degrees or senses of holism at hand, we shall proceed to examine Humphreys' claim that "Holism is insufficient for emergence because holistic properties can be possessed by systems that do not display emergent features,"[676] which seems

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[668] Humphreys, *Emergence: A Philosophical Account*, 66.
[669] Humphreys, *Emergence: A Philosophical Account*, 67.
[670] Humphreys, *Emergence: A Philosophical Account*, 136.
[671] "The term one, then, is used of all these things, namely, of what is continuous by nature, of a whole, of the singular thing, and of the universal." Aquinas, *Commentary on Aristotle's Metaphysics*, Book X, Lesson 1, Aristotle's Text Chapter 1: 5, p.633.
[672] "[a thing is one if it]"is a whole and has some form or specifying principle; and a thing is one to the greatest degree if it is such by nature and not by force (as those things which are united by glue or by a nail or by being tied together) and has in itself the cause of its own continuity." - Aquinas, *Commentary on Aristotle's Metaphysics*, Book X, Lesson 1, Aristotle's Text Chapter 1: 2, 633.
[673] Aquinas, *Commentary on Aristotle's Metaphysics*, Book X, Lesson 1, Aristotle's Text Chapter 1: 2, 633.
[674] Aquinas, *On the Principles of Nature*, 1-5.
[675] Aquinas, *Commentary on Aristotle's Metaphysics*,Book X, Lesson 1, Aristotle's Text Chapter 1: 2, 633.
[676] Humphreys, *Emergence: A Philosophical Account*, 37.

always false in the case of **holism by substantial forms**. As discussed in **Section V.5.1**, a substantial form is a principle of actuality that causes the "substantial existence"[677] of a distinct substance by functioning as the intrinsic principle of specification and unity, or oneness, or holism of that substance through organizing all the elements of that substance according to its kind-specific nature so that the substance exists as a unity with holistic or systems-level properties and causal powers proper to itself in ways irreducible to its components.[678]

Moreover, as discussed in **Section V.6.1**, Stump argues that such substances (e.g., a water molecule) are 'emergent'[679] precisely because of their holistic or systems-level properties and causal powers[680] conferred upon them by their substantial forms that are "irreducible to the features of [their] constituents taken singillatim"[681] outside of the organizations of these substances. Quite contrary to Humphreys' claim, therefore, holism is always sufficient for emergence in the case or degree of substances and their 'substantial holism' (**holism-S)** because the holistic features that they possess via their substantial forms are precisely what makes them emergent.[682]

Regarding the weaker degree of holism resulting from *accidental forms*, the situation is less straightforward because some accidental forms, e.g., that of an axe, do not seem to bring about emergent features above their holism.[683] Yet, as discussed in **Section VI.1**, some other accidental forms like the extrinsic objective specificative forms, including the quantum potentials

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[677] Aquinas, *On the Principles of Nature*, 1-5.

[678] Stump, "Emergence, Causal Powers," 53.

[679] "a whole...W is an emergent thing if and only if the properties and causal powers of W are not simply the sum of the properties and causal powers of the constituents of W when those constituents are taken singillatim, outside the configuration of W." - Stump, *Aquinas*, 43.

[680] e.g., the water molecule's uneven charge distribution, the ability to alter the configurations of its constituents, the oxygen and hydrogen atoms, and its causal power to form hydrogen bonds. See Section V.6.

[681] Stump, "Emergence, Causal Powers," 61.

[682] Given the interrelatedness of the Aristotelian four causes, the substantial form of an emergent entity will also result in the fulfillment of its other three criteria of emergence: novelty (material cause), autonomy (efficient cause), and and qualitative Newness. See this thesis, Section V.6.1. above.

[683] Stump, *Aquinas*, 44.

of the double-slit experiment (**Section VI.1**) and Quantum Entanglement (**Section VI.2**), do bring about emergent features, e.g., wave-like behaviour and correlated state, via their holisms. A distinction thus need to be made between the degree of *holism by emergence-causing-accidental forms* **(holism-ECAFs)**, and the degree of *holism by non-emergence-causing-accidental forms* (**holism-NECAFs)**.

As discussed in **Section VI.3**, a Bohmian approach to the key difference between *emergence-causing* and *non-emergence-causing-accidental-forms* is that *the latter* only causes a weak degree of holism by aggregating certain things via, in Aquinas' words, arrangement, or contact and bond,[684] without adding anything qualitatively new to them. Humphrey's example in this objection, i.e., "The number of objects in a finite collection of discrete entities"[685] is precisely the result of this kind of weak holism (holism-NECAF**)**. Whereas emergence-causing-accidental forms, such as the quantum potential Q of entangled systems, *do* add features qualitatively new and emergent (e.g., entangled state) to the objects they organize because they, in Aquinas' words, 'alter'[686] their component, or in Bohm's words, constitute 'pools of common information'[687] which in-form their components to participate in a common "dance"[688] they cannot perform when "taken singillatim."[689]

The emergence-causing accidental forms (ECAFs), at least in the case of the double-slit experiment and quantum entanglement, thus appear to be more then their non-emergence-causing relatives because ECAFs not only 'put things together' externally, but also in some sense become, as Hiley (2002) describes, "internal"[690] to what they organize by having a

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[684] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 3, 779, p.287.
[685] Humphreys, *Emergence: A Philosophical Account*, 37.
[686] Aquinas, *Commentary on Aristotle's Metaphysics*, Book Five, Lessons 3, 779, p.287.
[687] Bohm and Peat, *Science, Order, and Creativity*, 193.
[688] Bohm, Hiley, and Kaloyerou, "An Ontological Basis for the Quantum Theory," 334.
[689] Stump, "Emergence, Causal Powers," 61.
[690] Hiley, "From the Heisenberg Picture to Bohm," (16) 141-162 .

"formative"[691] effect on them from within. Emergence-causing accidental-forms (ECAFs) might thus constitute a distinct class of formal cause in between the generic or non-emergence-causing-accidental-forms and substantial forms: ECAFs are like the generic accidental forms since they are external to what they organize; yet, like substantial forms, ECAFs can become internal to what they organize to some degrees thereby 'forming' them from within, causing a degree of holism sufficient for emergent features (holism-ECAFs). This unique class of accidental forms may thus be termed '*Extrinsic-intrinsic exemplary forms*.' Hence, Humphreys' first objection[692] turns out to be insufficient in discarding holism from emergence because as just illustrated that holism comes in degrees (holism-NECAFs, holism-ECAFs and holism-S) and some degrees of holism (holism-ECAFs and holism-S) *are* sufficient for emergence at least in the sense of ontological fusion emergence (See Section V.3).

To objection (2) I answer that 'diachronic' emergence cannot function independently apart from or replace holism/synchronic emergence because transformations between 'simple' fundamental entities still involve holism, and diachronic emergence without holism fails to overcome mechanical atomism (which Humphreys terms "Generative Atomism"[693]) sufficiently.

Specifically, recall it was mentioned in **Section V.5.2** that it is disputed whether the fundamental particles are Aristotelian substances or even genuine 'particles'.[694] Humphreys seems to assume that they are at least concrete entities that " "have no components, "no internal structure," and "are not composed of quarks."[695] Yet, from an Aristotelian-Thomistic perspective, even fundamental particles that are 'simple' in this sense of having no material components or parts still exhibit a kind of *holism between their form and matter*. This affirmation of holism in

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[691] Hiley, "From the Heisenberg Picture to Bohm," (17) 141-162 .

[692] "Holism is insufficient for emergence because holistic properties can be possessed by systems that do not display emergent features."- Humphreys, *Emergence: A Philosophical Account*, 37.

[693] Humphreys, *Emergence: A Philosophical Account*, 141.

[694] See Koons, "Thermal Substances," 1-22.

[695] Humphreys, *Emergence: A Philosophical Account*, 66.

the fundamental particles is not, as Humphreys seems to suggest, an unnecessary result of taking "compositional approaches to ontology"[696] like hylomorphism because a hylomorphic or form-matter approach to material things seems hard to avoid given an understanding of matter suggested by the quantum theory as "a kind of indefinite corporeal substratum"[697] akin to Aristotle's prime matter invoked by Heisenberg (see **Section V.5.2.)**. Plainly, if energy is understood as the mere corporeal substratum conserved from the transformation of one fundamental entity to another, e.g., a muon to an electron, a neutrino, and an antineutrino, another principle is thus required in addition to energy to explain why the energy involved in this transformation was previously organized as an electron and now a muon. For Aristotelian-Thomists, this 'additional' principle is precisely *form* as actuality, and different forms, such as the form of an electron or muon, will then explain why the energy was preciously organized as an electron and now a muon. From a hylomorphic perspective, therefore, even fundamental entities are 'wholes' between their form and matter, and if one assumes these entities to be genuine substances, their forms would then be substantial forms, which would cause the entities' emergent status 'synchronically' via the highest degree of holism (**holism-S**) discussed above. The so-called 'diachronic' emergence, from a hylomorphic perspective, seems to be really a description for the coming-to-be, or in traditional Scholastic terms, the 'substantial change'[698] of an emergent substance as a composite between a substantial form or emergence-causing-accidental form and matter. Synchronic and diachronic accounts of emergence thus turn out to be two aspects of emergent entities on a hylomorphic analysis: the former accounts for the form-matter unity of emergent entities, whereas the latter accounts for their coming-to-be or

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[696] Humphreys, *Emergence: A Philosophical Account*, 140.

[697] See Heisenberg, *Physics and Philosophy*.

[698] For a detailed study of Aquinas' writings on substantial change, see Steven Ledinich. "A Study of Substantial Change In the Writings of St Thomas Aquinas" (PhD diss., Australian Catholic University, 2018).

substantial change.

Moreover, Humphreys' suggestion that diachronic emergence, since it holds that fundamental entities are transformational, can thus undermine mechanical atomism by disproving atomism's thesis that the fundamental entities are "immutable"[699] seems unconvincing because whether the fundamental entities can transform or not, it is essential to atomism, as Bohm argues, that reality is seen as ultimately reducible to their microphysical parts.[700] A transformational or diachronic approach to emergence without holism, however, seems to flatten out emergence as it now lacks any ability to challenge the microphysicalist-reductionistic worldview of atomism: for this reason, one may as well term 'transformational emergence' 'transformational atomism' (which makes no advancement from the position of Descartes).[701] Diachronic emergence thus cannot take on atomism except in unity with synchronic emergence that expands the fundamental ontology of atomism to include irreducible 'wholes.'

Furthermore, the true value of diachronic emergence, as Humphreys rightly notes, lies in its ability to highlight that when a holistic and emergent entity appears, a transformation has truly occurred because an emergent entity over and above the interaction of its parts has come into existence.[702] This way, a vicious causal loop of 'parts causing the whole and the whole in turn causing the parts', which, as Kim famously argues,[703][704] ultimately reduces the power of the

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[699] Humphreys, *Emergence: A Philosophical Account*, 141.

[700] Bohm, *Unfolding Meaning*, 1-2.

[701] "Democritus also imagined certain small bodies having various sizes, shapes and motions, and supposed that every sense-perceptible body is the upshot of assemblage and mutual interaction of these little corpuscles...Of course not!—no-one can doubt that there are many such particles, as I have just shown.Here are the four reasons why the philosophy of Democritus has been rejected. (1) **He supposed his corpuscles to be indivisible—a thesis that puts me in the 'rejection' camp**." **-** Descartes, *Principles of Philosophy*, 70. Emphasis mine.

[702] Humphreys, *Emergence: A Philosophical Account*, 127.

[703] Kim, "Making Sense of Emergence," 3-4.

[704] For more details on an Aristotelian-Thomistic treatment of the part-whole relationship, see Ross D. Inman, *Substance and the Fundamentality of the Familiar: A neo-Aristotelian Mereology* (New York: Routledge,

whole to the prior actions of the parts thereby collapsing the emergent status of the whole, can be avoided. Indeed, from an Aristotelian-Thomistic perspective, an entity is emergent precisely because it exhibits a degree of existence proper to itself, which came into existence by virtue of its form-matter composition irreducible to even their prior causes (See Section **V.6.1**). Diachronic emergence thus affirms the emergent status of holistic entities as rooted in the coming-into-existence ('substantial change'[705]) of their unique existence conferred upon them by their form-matter unity rather than their prior efficient causes.[706] Therefore, synchronic (holism) and diachronic (the coming-to-be of holism) accounts of emergence are not oppositions but different aspects of the same emergent wholeness.

VII.2.: Objections Against the Bohmian Interpretation From the 'Usual Interpretation' of Quantum Physics.

The Bohmian Interpretation is another 'pillar' of this essay. As stated by Bohm and Peat (1987),[707] however, many physicists have rejected the Bohmian Interpretation despite its innovative insights because, as Bohm and Peat argue, that they have "become habituated" by the "usually accepted interpretations"[708] of quantum physics. According to Bohm, this 'usual' interpretation of quantum physics is rooted in the indeterminacy principle, the idea that there is a "fundamental limitation" in the "quantum-mechanical level" such that "we are unable to obtain the data needed to specify completely the initial values of the various parameters"[709] like "the position and the momentum variables"[710] that "determine the behaviour of...a mechanical

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2017) and Robert Koons, "Staunch vs. Faint-hearted hylomorphism: Toward an Aristotelian account of composition," *Res Philosophica* 91, no. 2 (2014): 151-177.

[705] Ledinich, "A Study of Substantial Change In the Writings of St Thomas Aquinas."

[706] For more discussions on the conception of emergence based on formal vs efficient causes, see Tabaczek, "The Metaphysics of Downward Causation: Rediscovering the Formal CAUSE," *Zygon*® 48, no. 2 (2013): 380-404.

[707] Bohm and Peat, *Science, Order, and Creativity*, 97-101.

[708] Bohm and Peat, *Science, Order, and Creativity*, 98.

[709] Bohm, *Causality and Chance In Modern Physics*, 84.

[710] Bohm, *Causality and Chance In Modern Physics*, 85.

system."[711] Instead of treating the indeterminacy principle as a result of the limitations of physics's current state, however, many physicist have "adopted the hypothesis of Heisenberg...they assume that this principle represents an absolute and final limitation on our ability to define the state of things by means of measurement of any kinds that are now possible or that ever will be possible."[712]

Heisenberg's position was reinforced by von Neumann's theorem[713] according to which not only is it "impossible to verify *experimentally* any causal theory that aimed to predict the detailed behaviour of an individual system at the atomic level, but it is impossible even to *conceive* of such an explanation" because "nothing even exists corresponding to a set of "hidden" parameters having a degree of precision of definition"[714] beyond the 'measurement limit.' Bohm highlights that one consequence of Heisenberg's and von Neumann's positions is a "renunciation of causality"[715] in the quantum theory because "Real and observable physical phenomena"[716] like the irregular fluctuation of individual quanta upon observation[717] need now to be "assumed to have no causes,"[718] since Heisenberg and Neumann have deemed that no such causes or any factors can even exist beyond the measurement limit of the quantum-mechanical realm.[719] Hence, the results of quantum mechanical experiments must now be considered as obtained in a "completely arbitrary"[720] fashion, given their supposed lack of causality.

Heisenberg's and von Neumann's renunciation of causality was further reinforced by Niels Bohr, who held "the measuring apparatus and observed object as a *single indivisible*

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[711] Bohm, *Causality and Chance In Modern Physics*, 84.
[712] Bohm, *Causality and Chance In Modern Physics*, 85. Emphasis added.
[713] J.von Neumann, *Mathematische Grundlagen der Quantenmechanik* (Berlin: Springer-Verlag, 1932).
[714] Bohm, *Causality and Chance In Modern Physics*, 86.
[715] Bohm, *Causality and Chance In Modern Physics*, 84. Emphasis added.
[716] Bohm, *Causality and Chance In Modern Physics*, 86.
[717] Bohm, *Causality and Chance In Modern Physics*, 86-87.
[718] Bohm, *Causality and Chance In Modern Physics*, 86-86.
[719] Bohm, *Causality and Chance In Modern Physics*, 86-87.
[720] Bohm, *Causality and Chance In Modern Physics*, 86-87.

system" that "cannot correctly be analysed."[721] Therefore, the 'usual interpretation' of quantum physics gives up altogether the notion that some causes yet unknown may be behind quantum phenomena, which thus must be "completely arbitrary and lawless."[722] The business of physics, following the usual interpretation, is thus not to search for intelligible causes of quantum phenomena but to only "engage in purely technical manipulations of mathematical symbols according to suitable prescriptions which it is the business of theoretical physicists to discover."[723] This usual or 'shut-up and calculate' interpretation of quantum physics is thus the fundamental reason why the Bohmian Interpretation, or any interpretation that 'dares' to search for causes behind quantum phenomena are met with rejection and hostility.[724]

As such, (at least) two rebuttals can be offered against the 'usual interpretation' and its dismissal of the Bohmian Interpretation: **1.**The usual interpretation does not sufficiently justify its renunciation of causality and causal interpretations of quantum physics like Bohm's via the indeterminacy principle. **2.** Because of its renunciation of causality, the usual interpretation (like the way Aristotelian-Scholasticism was practiced in the Seventeen century) in fact hinders the continued development of science and thus ought to be jettisoned, as Newton would rightly remind us.

Regarding 1: The indeterminacy principle cannot rule out the possibility that there may be further factors yet unknown, such as "a sub-quantum mechanical level"[725] like the implicate order, that is responsible for the causality of quantum mechanical phenomena. Indeed, as Bohm argues, the conclusion that no further factors and causes exist beyond the quantum mechanical realm "is just a piece of circular reasoning, since it will follow only if we assume beforehand that

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[721] Bohm, *Causality and Chance In Modern Physics*, 86-89.
[722] Bohm, *Causality and Chance In Modern Physics*, 86-89.
[723] Bohm, *Causality and Chance In Modern Physics*, 86-97.
[724] Bohm, *Causality and Chance In Modern Physics*, 86-97.
[725] Bohm, *Causality and Chance In Modern Physics*, 86-94.

no such level exists."[726] Von Neumann's theorem will not support the usual interpretation either because it rests on the assumption that the specification of any systems will depend on what he calls "observables"[727] that "satisfy certain rules of the current quantum theory," which, as Bohm argues, "might break down, to be replaced" if "we go to a sub-quantum mechanical level."[728] Hence, both Heisenberg's indeterminacy principle and von Neumann's theorem cannot prove that no further causes and factors exist beyond the quantum mechanical phenomena, and the usual interpretation's rejection of the Bohm based on Heisenberg and Neumann's reasoning thus fails.

Regarding to 2, it ought to be noted that the usual interpretation is a result of the continued application of mechanical atomism into quantum physics. As discussed in **Section II and III**, mechanical atomism holds that no qualitative features like formal and final causes as well as qualities and causal powers can exist in physical reality beyond its quantitative aspects, and this position consequently causes mechanical atomism to conceive causation purely quantitatively as connection between events without being able to explain why they occur, leading critics like Locke and Berkeley to conclude that a scientific knowledge of physical objects is still "out of our reach"[729] within the mechanical context and that "the mechanical philosophers never explained any thing."[730]

Now, the usual interpretation in fact inherits all the above major features of mechanical atomism for it too postulates that no causes or factors may exist beyond the quantum mechanical phenomena, which then must be understood quantitatively as the result of "purely quantitative

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[726] Bohm, *Causality and Chance In Modern Physics*, 86-95.

[727] To which Bohm notes: "For example, their eigen values are obtained from linear Hermitean operators, their probability distribution from the square of the absolute value of the coefficient in a suitable expansion of the wave function."-Bohm, *Causality and Chance In Modern Physics*, 86-95.

[728] Bohm, *Causality and Chance In Modern Physics*, 86-95.

[729] Locke, *An Essay Concerning Human Understanding*, Book IV, Chapter III, 26.

[730] Berkeley, *Siris*, 108.

laws of probability fitting into a certain general physical and mathematical scheme that is absolute and final."[731] This "absolute and final"[732] characteristic of the usual interpretation is thus what places it in continuity with mechanical atomism, for they both deem that a further understanding of the world is impossible beyond the succession of events following quantitative laws.

Interestingly, this "absolute and final"[733] characteristic was precisely the reason Newton rejected the Aristotelians of his time: "And the Aristotelians gave the name of occult qualities, not to manifest qualities...Such occult qualities put a stop to the improvement of natural philosophy, and therefore of late years have been rejected."[734] By analogy, however, Newton's criticisms also apply to the usual interpretation and its philosophical root: mechanical atomism. For mechanical atomism too deems that their explanations are final and absolute, which would thus also "put a stop to the improvement of natural philosophy."[735] Mechanical atomism (of which the usual interpretation is a case) and the early modern Aristotelians critiqued by Newton were thus two extremes of the same camp: both sides deem their explanations to be final, yet one appeals to quantity and the other quality.

Yet, just as Newton responded to the Aristotelians not with a rejection of qualities but sought to make *manifested* certain true qualities like gravity and color (see **Section III.2**) via empirical research (which is the true spirit of Aristotelian-Scholasticism) thereby developing science further, Bohm too does not reject the quantitative equations and laws of the usual interpretation but seeks to search for their possible qualitative causes, like the implicate order and information, thereby opening an approach that allows for a continued development of

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[731] Bohm, *Causality and Chance In Modern Physics*, 86-103.
[732] Bohm, *Causality and Chance In Modern Physics*, 86-103.
[733] Bohm, *Causality and Chance In Modern Physics*, 86-103.
[734] From the *Opticks* of Newton as quoted in Koyré, *Newtonian Studies*, 145.
[735] From the *Opticks* of Newton as quoted in Koyré, *Newtonian Studies*, 145.

science. Bohm is thus a successor to Newton because both of them have maintained the classical Aristotelian understanding of science as knowledge of true causes.

Of course, just as Newton was accused by Leibniz of being an Aristotelian postulating occult qualities[736], Bohm was also criticized by proponents of the usual interpretation via a positivist undertone for postulating entities, like information and the implicate order, "which cannot be observed by methods that are *already available*."[737] Yet, Bohm argues that scientific progress is generally made by **1.** the development of new facts, "which ultimately lead to new kinds of concepts and theories," and **2.** "the explanation of...existing facts in terms of new concepts and theories, which ultimately lead to new kinds of experiments and thus to the discovery of new facts"[738] (of which Democritus' atomism, the medieval rediscovery of Aristotle, Faraday and Maxwell's field theory, Einstein's relativity etc., are examples). From a Bohmian perspective, the positivist position failed to recognize "the historically demonstrated fact that the proposal of new concepts and theories have certain speculative aspects...has quite frequently turned out to be just as important in the long run as new empirical discoveries have been."[739]

Far from presenting effective objections against the Bohmian Interpretation, therefore, the 'usual' interpretation in fact illustrates that physics require the kind of innovative insights found in the Bohmian Interpretation in order to keep open the possibility of further development.[740]

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[736] Newton, *Newton: Philosophical Writings*, 116.
[737] Bohm, *Causality and Chance In Modern Physics*, 86-97.
[738] Bohm, *Causality and Chance In Modern Physics*, 99.
[739] Bohm, *Causality and Chance In Modern Physics*, 100.
[740] For a critique of the Bohmian Interpretation from a hylomorphic perspective as well as a general comparison between the strengths and weaknesses of most major interpretations of quantum physics, including the Copenhagen, the Dualist, the Bohmian, the Many Worlds, the Objective collapse, and the hylomorphic interpretations, see Koons, "Multi-Scale Realism," especially p. 13-16 and the diagram on p.16. Koons criticizes the Bohmian interpretation on the ground that "Bohm's theory renders all of the classical world epiphenomenal and causally inert. All the *oomph* is located in the pilot wave, whose "shape" or contour is logically and metaphysically independent of the distribution of particles. The hylomorphic view, in contrast ... recogniz[es] that both classical objects and quantum objects exercise real, fundamental causal powers" - Koons, "Multi-Scale Realism," 14.

VII.3.: Objections Against Aristotelian-Thomism From Modern Mechanical Atomism.

Here, we revisit where we started: early-modern mechanical philosophers' rejection of Aristotelian-Scholasticism that launched a wave of reductionism which would be seriously challenged only centuries later by emergentism and the quantum revolution, which, ironically, initiated a retrieval of the Aristotelian-Thomistic metaphysics in contemporary philosophical and scientific spheres.[741]

To begin, recall it was discussed in **Section II.3** that early-moderns like Descartes dismissed key Aristotelian-Scholastic notions like formal causation based on the reasoning that they are "unintelligible...idle, unnecessary" because everything in the physical universe can supposedly be explained as "assemblage and mutual interaction of little...corpuscles"[742] and their quantitative features like "size, shape and motion" apart from which "No phenomenon of nature

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However, it seems to the author that Bohm's position does at least leave room for the recognition of the causal powers of macroscopic entities, given Bohm's affirmation that the implicate order, or the sub-quantum mechanical realm from which the pilot wave originates, is a "generative order" from which new kinds of existence, such as "particles," "living being, and even ... the conscious being," can "emerge" and enter into a state of "free play." - see Bohm and Peat, *Science, Order, and Creativity*, 193-203. Bohm's at least implicit affirmation of macroscopic entities' genuine existence and causal power is further illuminated by Hiley, who states that: "Because there is nothing to push against we should not regard the **quantum potential as giving rise to an efficient cause, ('pushing and pulling') but it should be regarded more in the spirit of providing an example of Aristotle's formative cause.** That is the quantum potential gives new form to the evolution of the trajectories, in a way that is very reminiscent of the morphogenetic fields proposed by Waddington (1956) and Thom (1975) in biology.**The form is provided from within** but it is, of course, shaped by the environment. Thus the quantum potential reflects the experimental conditions. Close one slit and the quantum potential changes and the subsequent evolution of the particle is different. **There seems to be a kind of 'self-organisation' involved**." - Hiley, "From the Heisenberg Picture to Bohm," (17) 141-162. Emphasis mine. As such, I propose that the Bohmian Interpretation, when correctly understood, is much more in line with Koons' 'hylomorphic' interpretation of quantum physics. The Bohmian Interpretation thus shares the various advantages of the hylomorphic interpretation over other major interpretations of quantum physics according to Koons' account. Again, see Koons, "Multi-Scale Realism."

[741] For example, see William M.R. Simpson, Robert C. Koons, and Nicholas J. Teh, *Neo-Aristotelian Perspectives On Contemporary Scienc*e (Oxfordshire: Taylor & Francis, 2018). Daniel D.Novotný, and Lukáš Novák, eds, *Neo-Aristotelian Perspectives In Metaphysics* (New York: Routledge, 2014). Robert C. Koons and Timothy Pickavance. *The Atlas of Reality: A Comprehensive Guide to Metaphysics* (Hoboken: John Wiley & Sons, 2017).

[742] Descartes, *Principles of Philosophy*, 70.

has been overlooked," or so declares Descartes in the *Principles of Philosophy.*[743] Traditional Scholastic notions like substantial form thus appeared needless to the modern mechanical mind and were thus dismissed, and the unparalleled success of modern science only seems to justify their position.

This essay, however, has attempted to illustrate that upon a closer analysis, the triumphant tale of mechanical atomism has never been quite true despite the success of modern science. For example, it was pointed out in **Section III.2** that Newton held colour [744] and gravity[745] to be manifested *qualities*, challenging the mechanistic narrative that all physical features of the world are quantitative. **Section IV** further presents a series of challenges to mechanical atomism arising from the continued progress of classical and quantum physics that reveal the reality of wholeness in nature especially as highlighted by Bohm, and is followed by **Section V.1-4** in which emergentism was introduced as a systematic interdisciplinary movement against mechanical atomism.

The progression from **Section III-V.1-4**, therefore, draws on a common line of reasoning: mechanical atomism is shown to be incapable of explaining *all* physical phenomena (especially qualities and the kind of holisms in nature highlighted by Bohm and emergence), which illustrates that mechanical atomism cannot give reality an exhaustive description despite its remarkable explanatory power in the quantifiable aspects of reality. As such, theoretical frameworks and explanatory principles other than mechanical atomism can rightfully be considered to account for and explain those phenomena, namely, qualities, holism and emergence, that mechanical atomism cannot explain. In fact, Humphreys argues that the many

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[743] Descartes, *Principles of Philosophy*, 69.
[744] Wallace, *Causality and Scientific Explanation*. *Vol.I*, 199-200.
[745] Koyré, *Newtonian Studies*, 144.

varieties of emergence theories are precisely motivated by "the failure"[746] of mechanical atomism to account for certain phenomena reductionistically.

Moreover, **Section V.5-7** and **VI** build on the previous sections and argue that holism and emergence can be precisely yet robustly articulated, understood, and defended by the classical notions of Aristotelian-Thomistic metaphysics, including potency and act, form and matter/hylomorphism, substantial and accidental forms, virtue presence, the Eight Causes, the categories, the principle of causality, ontological relation, etc. Aristotelian-Thomistic metaphysics has thus rightfully experienced a contemporary revival as an alternative metaphysics to atomistic-mechanistic metaphysics.

The early-modern philosophers' rejection of Aristotelian-Scholastic metaphysics has thus been over-turned on precisely the scientific ground which the former once used to reject the latter because the continued development of science has led to the discovery of phenomena like holism and emergence that can be helpfully explained by Aristotelian-Thomistic metaphysics but not by the atomistic-mechanical metaphysics. Aristotelian-Thomistic metaphysics thus should rightly be seriously considered by scientists and philosophers alike to be an alternative ontological framework (or 'themata' in Gerald Holton's terms) to mechanical atomism that can help us better understand the discoveries of contemporary science holistically. The relationship between Aristotelian-Thomistic metaphysics, science, and emergentism can thus be summed up as a two-way interaction: certain discoveries of science and claims of emergentism suggest that some views, principles, and notions of Aristotelian-Thomistic metaphysics to be valid and true, and these elements of A-T metaphysics can in turn effectively explain, articulate, and defend the discoveries and claims of science and emergentism.

It ought to be emphasized, however, that a supersession of mechanical atomism by

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[746] Humphreys, *Emergence: A Philosophical Account*, 4.

Aristotelian-Thomism does not mean that all elements and achievements of mechanical atomism should be abandoned. Rather, it means admitting that mechanical atomism is really only a small part (which emphasis efficient and material causalities) of a far richer worldview provided by Aristotelian-Thomism. Mechanical atomism is not wrong to uphold the importance of material and efficient cases; rather, its error lies in its conviction that these are the only real causes and that all reality can be reduced to them.[747] Aristotelian-Thomistic metaphysics, however, recognizes efficient and material causes and the many others kinds of causes beside them like formal and final causes and can thus account for phenomena, e,g, qualities, holism and emergence, that cannot be reduced to the parameters of mechanical atomism. Updated with contemporary science, therefore, Aristotelian-Thomistic metaphysics provides a sufficiently versatile yet sophisticatedly principled pluralistic ontology that keeps open the horizon of human knowledge, allowing it to grow indefinitely as our knowledge of it deepens gradually in time. The Aristotelian-Scholastic stone rejected by the early-modern builders has therefore become the corner stone, and everything old is new again.

Section VIII. Implications: Emerging from A Fractured World.

With these objections addressed, I would now like to point to a few of the many important implications that this shift of paradigm I have been exploring carries for our self-understanding and our current economic condition. Due to length limit, however, these discussions shall remain brief.

VIII.I. Philosophical Anthropology: The Human Person and Freedom.

Recall that this thesis started in **Section I** with Bohm's observation that the atomistic-mechanistic worldview has caused a decline in the society's general regard for the human person

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[747] Jacques Maritain, *Philosophy of Nature*, ed. Yves R. Simon, trans. Imelda C. Byrne (New York: Philosophical Library, INC, 1951).

and humanities studies because, as vividly expressed by Alex Rosenberg, the atomistic-mechanistic worldview reduces all reality, including human beings, to the fundamental particles[748] which entails that social sciences and humanities are mere "*post hoc* rationalizations"[749] of our otherwise physically determined behaviors that generate the illusions of self-consciousness and intentionality.[750]

From the perspective of this essay, however, Rosenberg's position results precisely from accepting a mechanical-atomist worldview ignorant of the emergent phenomena like holism in nature revealed by contemporary science that often renders reductionism impossible even in the atomic and quantum realms, as illustrated throughout this essay. The human existence, however, is infinitely more complex than atoms and quanta. In fact, a human being, for an Aristotelian-Thomist, is a representative Aristotelian 'substance' irreducible to its components by virtue of their substantial form and emergent or systems-level properties, especially their "mental properties"[751] like freedom.

As Stump[752] [753] argues, freedom for Aquinas is "an emergent property or a systems-level feature" of an entire human being resulting from "the dynamic interactions of intellect and will" and not from "some particular component of a human being."[754] Briefly, the **will** for Aquinas is an appetite or inclination towards the good[755] (more on Aquinas' notion of goodness below). Yet, the will understood as an appetite is without the ability to make particular judgements or determinations regarding goodness; rather, it is the function of the **intellect** to discern and

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[748] Alex Rosenberg, "Disenchanted Naturalism."
[749] Alex Rosenberg, "Disenchanted Naturalism."
[750] Alex Rosenberg, "Disenchanted Naturalism."
[751] Stump, "Emergence, Causal Powers," 65.
[752] Stump, *Aquinas*, 277-306.
[753] Eleonore Stump, "Aquinas's Account of Freedom: Intellect and Will," *The Monist 80*, no.4 (1997): 576-597.
[754] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576.
[755] "Now this is good in general, to which the will tends naturally, as does each power to its object." Aquinas, *Summa Theologiae*, I-II, q.10, a.1.

"[present] to the will as good certain things or actions...and the will wills them because it is an appetite for the good and they are presented to it as good."[756] The intellect is thus said by Aquinas to be a final cause that moves the will by discerning the goods, which are the ends that the will seeks after.[757] The will, however, can also move the intellect and "all the powers of the soul"[758] as an efficient cause because, on Aquinas' account, it is the will that moves in general every power of the soul, including the intellect, to attain their respective ends as "some suitable good proper to it,"[759] such as knowledge of good and evil. The will can also move the intellect in specific ways such as "command" the intellect to "stop thinking about something"[760] thereby indirectly turning itself off, etc. The intellect and will are thus situated in a very intimate and dynamic relationship for Aquinas, so much so that he sometimes holds them as "intertwined"[761] and hard to distinguish.

Now, Aquinas divides freedom into "freedom of action and freedom of willing"[762][763] because though the will can wish something, which is the will's "immediate act,"[764] the will also needs to bring what it wishes into action or execution by commanding "some other powers"[765], such as those of the body. The freedom of action for Aquinas can thus be jeopardized or "suffer violence, in so far as violence can prevent the exterior members from executing the will's

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[756] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-577-578.

[757] "A thing is said to move in two ways: First, as an end; for instance, when we say that the end moves the agent. In this way the intellect moves the will, because the good understood is the object of the will, and moves it as an end." - Aquinas, *Summa Theologiae*, I, q.82, a.4.

[758] Aquinas, *Summa Theologiae*, I, q.82, a.4.

[759] Aquinas, *Summa Theologiae*, I, q.82, a.4.

[760] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-580.

[761] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-581.

[762] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-583.

[763] "I answer that, The act of the will is twofold: one is its immediate act, as it were, elicited by it, namely, "**to wish**"; the other is **an act of the will commanded by it**, and put into execution by means of some other power." -Aquinas, *Summa Theologiae*, I-II, q.6, a.4. Emphasis added.

[764] Aquinas, *Summa Theologiae*, I-II, q.6, a.4.

[765] Aquinas, *Summa Theologiae*, I-II, q.6, a.4.

command."[766] The freedom of willing, however, is not so vulnerable to external violence because it is "nothing else than an inclination proceeding from the interior principle of knowledge,"[767] namely, the intellect that discerns the good. Both the freedoms of action and willing are thus for Aquinas "not a property of just one component of a human being;" rather, they are both properties of "a whole system."[768] The **freedom of action**, for example, "emerges when the will is freely commanding a certain sort of movement and when the relevant bodily parts are functioning normally" undisturbed by impediments. Similarly, the **freedom of willing** arises when interactions between the intellect and the will occur in ways described above.[769] [770]

As such, humans are free in Aquinas' view because our intellect or reason can present many perceptions of the good for the will to consider, and the will can accept them as ends to be pursued, or reject them, or commend the intellect to reconsider them, etc. This ability to wish and to act toward ends of our own choosing by virtue of powers arising from principles intrinsic[771] or "within"[772] us, namely, the intellect and the will, is thus what makes humans free agents and true masters of their own actions for Aquinas.[773] [774] [775] Human freedom for Aquinas is thus a systems-level property or "an emergent power or property resulting from the dynamic interaction between

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[766] Aquinas, *Summa Theologiae*, I-II, q.6, a.4.

[767] Aquinas, *Summa Theologiae*, I-II, q.6, a.4.

[768] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-583.

[769] "The root of liberty is the will as the subject thereof; but it is the reason as its cause. For the will can tend freely towards various objects, precisely because the reason can have various perceptions of good. Hence philosophers define the free-will as being "a free judgment arising from reason," implying that reason is the root of liberty." -Aquinas, *Summa Theologiae*, I-II, q.17, a.1.

[770] Aristotle also describers this power of a human being to conceive many possibilities and choose particular ones from them as 'rational potency:' "Hence the soul will initiate both by the same principle by joining both to the same rational plan. And for this reason those things whose potency is rational produce effects contrary to those potency is irrational; for one principle of contrary determinations is contained in the rational plan."-Aquinas, *Commentary on Aristotle's Metaphysics*, Book Nine, Lesson 2, Aristotle's Text Chapter 2: 4, p.590.

[771] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-584.

[772] Aquinas, *Summa Theologiae*, I-II, q.6, a.1.

[773] Aquinas, *Summa Theologiae*, I-II, q.6, a.1.

[774] Aquinas, *Summa Theologiae*, I-II, q.1, a.1.

[775] Terence Irwin argues that the medieval notion of 'voluntas' or a voluntary will is not a medieval Christian convension but something already found in Aristotle's notion of *boulasis* or wishing. See Terence H. Irwin, "Who Discovered the Will?" *Philosophical Perspectives* 6 (1992): 453-473. https://www.jstor.org/stable/2214256#metadata_info_tab_contents.

the intellect and will rather than a static power localized in the structure of one particular faculty."[776]

From the viewpoints of emergentism and Aristotelian-Thomistic metaphysics (**Section V and VI**), *freedom* in Aquinas' account amounts to a kind of *novel* feature or power irreducible to any of a person's particular element precisely because it is a case of *holism*. A person's intellect alone, for example, is not free because even though it can conceive many notions, it lacks the motive power to act on any of them. Without the intellect, however, the will may have the power to choose but have nothing to choose from. Moreover, still more human functions such as sensation, the passions, etc, would of course also need to be involved if the intellect and will are to function properly. Therefore, freedom, as a property more properly attributed to an entire human being[777] rather than any of their particular elements, is thus a sign that the person is an **autonomous** and **qualitatively new**, that is, an emergent entity or Aristotelian substance exhibiting its own substantial form. Bringing this to bear on Bohm's Interpretation, the wholeness in nature is not restricted to the quantum realm but is also found in the macroscopic world within the living and breathing human beings[778] that we constantly see face to face.

If human beings are indeed such emergent and holistic substances, this means the kind of reductionism of human existence to the fundamental particles, and human knowledge to the facts of particle physics exemplified in the thoughts of Rosenberg[779] is completely wrong headed, for a holistic and emergent entity must be understood on its own terms. Otherwise, those novel and qualitatively new features, e.g., freedom, that make such an entity unique would be lost in our discourses, and this is precisely why disciplines proper to the human person,e.g., the social

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[776] Stump, "Aquinas's Account of Freedom: Intellect and Will," 576-588.
[777] Stump, "Aquinas's Account of Freedom: Intellect and Will," 588.
[778] Bohm and Peat, *Science, Order, and Creativity*, 200-223.
[779] Alex Rosenberg, "Disenchanted Naturalism."

sciences and humanities, must exist so that the experiences, values, and knowledge proper to the person on their own level are adequately acknowledged and accounted for in our academic discourses and social-political interactions. In this next portion, we shall look into two of those values that an Aristotelian-Thomistic metaphysics combined with emergentism could help us to acknowledge and to preserve: goodness and human flourishing.

VIII.2. Moral Philosophy: Goodness and Human Flourishing.

If human freedom is pre-occupied with a search for the human good as our *telos* or ends for Aquinas, what then is this 'good' or goodness? Aquinas, following a long tradition before him[780], conceives the goodness of a thing transcendentally as convertible with its state of being[781] [782] "complete, whole, and free from defect," which is a thing's "being fully actual."[783] This state of "full actualization"[784] or goodness without lacking any perfections or virtues proper to us is thus our "perfect good" and "last end"[785] toward which our intellect and will freely aspire.One further question, however, is what are these perfections or virtues by which we can be fully actualized in goodness. Aquinas answers this question by, *firstly*, making a distinction between *first actuality*, which is the "form and integrity of a thing," and *second actuality*, "which is "its operation,"[786] and, *secondly*, by arguing that a thing is perfect and good if it **(a)**

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[780] For a detailed study on this subject, see MacDonald, Scott Charles, and Scott MacDonald, eds., *Being and Goodness: The Concept of the Good in Metaphysics and Philosophical Theology* (Ithaca: Cornell University Press, 1991).

[781] "Goodness and being are really the same, and differ only in idea."- Aquinas, *Summa Theologiae,* I, q,5, a,1.

[782] "For that by which each thing is called good is the virtue that belongs to it; for "the virtue of each thing is what makes its possessor and his work good." Now, virtue "is a certain perfection, for each thing is then called perfect when it reaches the virtue belonging to it," as may be seen in Physics VII [3]. Hence, each thing is good from the fact that it is perfect. That is why each thing seeks its perfection as the good belonging to it."-Aquinas, *Summa Contra Gentiles*, I, 37, 2.

[783] Stump, *Aquinas*, 63.

[784] Stump, *Aquinas*, 63.

[785] Aquinas, *Summa Theologiae,* I-II, q,1, a,6.

[786] Aquinas, *Summa Theologiae*, I, q,48, a,5.

exhibits first actuality[787] via a nature or substantial form that determines its species[788], and **(b)** it "performs instances of its specific operation[or second actuality] and thereby actualizes its specifying [or species-specific] potentiality" whereby "bring[ing] into actuality what was not actual but merely potential in that thing's nature as conferred by its substantial form."[789] [790]

Now, humans exhibit a rational substantial form (*first actuality*), which bestows upon us, amongst other things, two crucial powers, *VIZ*., the intellect/reason and the will/appetite. Stump helpfully points out[791] that these two powers are taken by Aquinas as the two fundamental "principles of human actions."[792] Human *second actuality* is therefore for Aquinas a matter of operating or living according to the 'virtues' that are habits or states that perfect either our intellect or will.[793] The habituation of the virtues thus leads to human beings' full actualization or flourishing[794] as depicted by Aristotle's classical notion of *eudaimonia* as "activities of the soul with conformity in virtue."[795] Furthermore, Aristotle identified those virtues that perfect the intellect as the *intellectual virtues*, including "craft, scientific knowledge, prudence, wisdom, and understanding,"[796] and those that perfect the appetite/will as the ***moral or character virtues***, including., justice, temperance, and fortitude,[797] etc. Moreover, Aquinas adds over and above these 'natural virtues' the theological virtues of faith, hope, and charity, emphasizing that charity

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[787] Stump, *Aquinas*, 66.
[788] Aquinas, *Summa Theologiae,* I, q,5, a,5.
[789] Stump, *Aquinas*, 67.
[790] Aquinas, *Summa Theologiae,* I-II, q,3, a,2.
[791] Stump, *Aquinas*, 70.
[792] Aquinas, *Summa Theologiae*, I-II, q,58, a,3.
[793] Aquinas, *Summa Theologiae,* I-II, q,58, a,3.
[794] The intelligible aspects of flourishing are concisely summed up by new natural law theorists such as John Finnis' as the various 'basic forms of human good' that are to be ubiquitously upheld in all human activities without arbitrary preferences: "1. life, 2. knowledge, 3.play or skillful performance, 4.aesthetic experience, 5.sociability (friendship), 6.practical reasonableness, and 7.religion."- See John Finnis, *Natural Law and Natural Rights* (Oxford: Oxford University Press, 2011), 86-89.
[795] Aristotle*, Nicomachean Ethics: Translated With Introduction, Notes, and Glossary by Terence Irwin,* I, C7, S15, P.10.
[796] Aristotle*, Nicomachean Ethic,* VI, C3, S1, P.103.
[797] Aquinas, *Summa Theologiae,* I-II, q,61, a,2.

("the friendship of man for God"[798]) is the "form of the other virtues" because, as love, charity is the essence and final fulfillment of humankind's highest goodness and full actualization realized in our union with God in the *beatific vision*[799] [800] through "Jesus Christ...the one and only mediator between God and man,"[801] from whose love all other virtues spring fourth and to which all of them tend toward.[802]

From an Aristotelian-Thomistic perceptive, the goodness and inherent value of human beings as emergent substances thus consist in their irreducible substantial being or first actuality and their second actuality that is their teleological movement toward the virtues, flourishing, and, ultimately, God, powered by human freedom and grace. Such a transparently qualitative account of human goodness, however, is fundamentally opposed to our society's prevalent treatment of people's value in strictly quantifiable terms, including how useful or expendable a given person is when it comes to generating profits, fulfilling certain tasks, playing certain roles, etc., all of which consider human beings as primarily 'means to an end.' Evidently, this pragmatic attitude toward the person has its root in our tendency to look to the 'parts' for practical purposes in dismissal of the whole, which has been increasingly justified in and amplified by the atomistic-mechanistic worldview, which, as Bohm points out, is "indifferent" to the person's "aspirations, goals, moral and aesthetic values, and, indeed, to his ultimate fate."[803] Yet. a replacement of mechanical atomism by Aristotelian-Thomism forces one to recognize the whole, such as the person's irreducible substantial being and goodness, their dignity, their need for flourishing and

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[798] Aquinas, *Summa Theologiae,* II-II, q,23, a,1.
[799] Aquinas, *Summa Theologiae,* Supplement, q,92, a,1.
[800] Aquinas, *Summa Theologiae,* II-II, q,23, a,7. For an application of Aristotelian-Thomistic metaphysics to theology especially against Karl Barth's criticism of natural theology, see Thomas Joseph White, "How Barth Got Aquinas Wrong: A Reply to Archie J. Spencer on Causality and Christocentrism," *Nova et Vetera* 7 (2009): 241-270. https://philpapers.org/rec/WHIHBG.
[801] *Catechism of the Catholic Church* (CCC), 2nd ed., 480.
[802] Aquinas, *Summa Theologiae,* II-II, q,23, a,8.
[803] Bohm, *Unfolding Meaning*, 1-2.

freedom, etc., as elements that are largely missing from our society's equations. This paradigm shift will have implications for how we understand and operate our social-political and economic institutions.

Examples: Economy, Market, and Corporation.

For example, Harvard economist Mary L. Hirschfeld argues in her book *Aquinas and the Market: Toward a Humane Economy*, that the main stream "economic worldview"[804] of the West "is not value neutral" because "Main stream economics," in the same way as mechanical atomism, "is tacitly grounded in its own metaphysics"[805] that focuses on the quantifiable and mathematizable aspects of reality.[806] As a result, main stream economics consider human beings on quantitative terms as a "*homo economicus*,"[807] a type of "individualistic and self-seeking"[808] being preoccupied with "allocate[ing] their scarce resources (mostly income and time) to acquire the most desirable bundle of goods available to them."[809] Under this model, all human actions are "morally equivalent,"[810] regardless if it is Hitler's deplorable evil or Mother Teresa's acts of kindness because they are all just results of humans acting as *homo economicus* by using most effective means to acquire their desired goods. Moreover, all human actions can be reduced to a weighing of "trade-offs"[811] according to this model, which seemingly renders any action, including any kind of exploitation permissible, "if the expected benefits of doing so outweigh the expected costs."[812] [813] Consequently, the outcomes of implementing these main stream economic

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[804] Mary L. Hirschfeld, *Aquinas and the Market: Toward a Humane Economy* (Cambridge: Harvard University Press, 2018), p.viii.
[805] Hirschfeld, *Aquinas and the Market*, xviii.
[806] Hirschfeld, *Aquinas and the Market*, x.
[807] Hirschfeld, *Aquinas and the Market*, viii.
[808] Hirschfeld, *Aquinas and the Market*, ix.
[809] Hirschfeld, *Aquinas and the Market*, viii.
[810] Hirschfeld, *Aquinas and the Market*, x.
[811] Hirschfeld, *Aquinas and the Market*, xi.
[812] Hirschfeld, *Aquinas and the Market*, x.

theories for the sake of "fostering happiness"[814] is "problematic."[815] Instead of holding onto the quantitative models of main stream economics, Hirschfeld argues that a retrieval of Aquinas' account of "human nature" and our "quest for happiness"[816] could replace the quantitative model and deliver "a vision of a humane economy, one that is in service to genuine human flourishing."[817]

Hirschfeld's insight is echoed by Douglas Rushkoff, who argues that modern Western corporations, e.g., Walmart, should abandon their quantitative and value-extraction based paradigm (which often holds share-price as the single measurement of success[818]) that damages the very foundation of free-market economy: peer-to-peer value creation.[819] This paradigm, which Rushkoff terms 'industrialism', often leads to long term repercussions, including an increasing lack of ability for modern day U.S. corporations to generate value or 'return on assets,'[820] increased "poverty rates and welfare expenses,"[821] and the eventual bankruptcy of the communities in regions where the corporations operate. Instead, Rushkoff argues that business corporations ought to abandon their self-destructive quantitative value-extraction model by starting to invest in human flourishing thereby encouraging value creation through, for example,distributing their stocks among its employees so that the workers can enjoy the real fruit of their works (successfully implemented by Publix Super Market), investing certain percentage

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[813] For fans of Star Trek, what comes to mind after reading this description of *homo economicus* is perhaps the Ferengies,whose sole purpose is to maximize profit with minimal cost, following their economic theory summed up in a book called the *Rules of Acquisition* that seemingly allows for exploitation of any kind.

[814] Hirschfeld, *Aquinas and the Market*, p.xi.

[815] Hirschfeld, *Aquinas and the Market*, p.xi.

[816] Hirschfeld, *Aquinas and the Market*, p.xv.

[817] Hirschfeld, *Aquinas and the Market*, p.xvi.

[818] Douglas Rushkoff, *Throwing Rocks At The Google Bus* (New York: Penguin Random House LLC, 2017), 113.

[819] Rushkoff, *Throwing Rocks At The Google Bus,*70.

[820] Rushkoff, *Throwing Rocks At The Google Bus,*72.

[821] Rushkoff, *Throwing Rocks At The Google Bus,*72.

of their profits in the development of small business and communities as 'benefit corporations'[822] (successfully implemented by Canadian Tire), etc.

Hirschfeld and Rushkoff's call for economical and social reforms based on a central concern for the flourishing of human beings as irreducible to quantifiable numbers is precisely the kind of humanist spirit and insight that this essay has laboured to defend and bring forward by arguing for a supersession of reductionistic atomistic-mechanical worldview with the holistic and pluralistic neo-Aristotelian-Thomistic worldview. Neo-Aristotelian-Thomism, as a new intellectual culture replacing that of the early modern mechanical one, thus frees us from conceiving of the world as a vast collection of meaningless particles in motion and enables us to envision a world that recognizes, respects, and even promotes the value, freedom, dignity, and flourishing of irreducible 'wholes' like humans beings and the many things of nature.[823] I now must leave the readers to further explore these possibilities.

Section IX. Conclusion. In **Section I**, this essay identified modern mechanical atomism as a key element in our worldview that is responsible for society's increasing disregard for the human person and the academic disciplines of the social sciences and the humanities. In **section II**, mechanical atomism was criticized for its inability to philosophically justify its reductionistic worldview. This was followed by **section III** in which crucial scientific developments in both classical and quantum physics were recognized to contradict the microphysical reductionism of mechanical atomism. **Section IV** focused on David Bohm's unique perspective on wholeness as revealed by the quantum revolution, and Bohm's insights on wholeness were synthesized in **Section V** and **VI** with Emergentism and Aristotelian-Thomistic metaphysics.

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[822] Rushkoff, *Throwing Rocks At The Google Bus,* 119.

[823] For an application of Thomistic metaphysics to environmental ethics, see Marie I. George, "Aquinas on the Goodness of Creatures and Man's Place in the Universe: A Basis for the General Precepts of Environmental Ethics," *The Thomist: A Speculative Quarterly Review* 76, no. 1 (2012): 73-123. See also Willis Jenkins, *Ecologies of Grace: Environmental Ethics and Christian Theology*. (Oxford: Oxford University Press, 2013).

This synthesis between Aristotelian-Thomism, Emergentism, and the Bohmian Interpretation was then defended in **Section VII** and concretely applied to philosophical anthropology, freedom, moral philosophy, goodness, human flourishing, and broader social-economic practices in **Section VIII**. The central aim of this essay is to illustrate that the reductionistic worldview still prevalent in academia and the wider public sphere is a remnant of an early modern understanding of science that, though once useful, has now been shown to be inadequate and detrimental to both of our understanding of the world and the human person, and that a retrieval of Aristotelian-Thomistic metaphysics can supply us with a worldview that not only accounts for the parts but also sees the whole so that we can coherently understand and hold together the spectatular power of science and the wonders of human existence, freedom, value, dignity, and flourishing to thereby establish a metaphysical basis for a more humane world. My hope is that this thesis will foster further discussions addressing the joint implications of philosophy, contemporary science, and other disciplines so that we people of the twenty-first century may start to heal and emerge from the fractured world that we inherited and move toward a new world spirit that recognizes the cosmos as the intrinsically meaningful and ontologically "dappled"[824] plane of existence that it is.

[824] Nancy Cartwright, *The Dappled World: A Study of the Boundaries of Science* (Cambridge: Cambridge University Press, 1999).

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