Philosophers' Imprint

volume 21, no. 5
january 2021

# On the Ultimate Origination of Things

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## 1. Introduction

The problem of determining the ultimate origin of things is one of the oldest problems in philosophy. Here, we propose a new solution to this old problem based on advances in general dynamics, the universal theory of physical force or action. Although our article was prompted in part by Leibniz's famous essay on the origin of things, from which it also takes its title, it does not furnish a scholarly critique of that essay. Instead, it employs a provocative argument contained therein to frame and orient a contemporary discussion of the subject, one that in due course arrives at conclusions that differ from Leibniz's own but are supported by the principles of modern physics.[1]

Leibniz begins his essay by rejecting the idea that the reason for the universe's existence can be found by looking to the universe itself:

> I certainly grant that you can imagine that the world is eternal. However, since you assume only a succession of states, and since no reason for the world can be found in any one of them whatsoever (indeed, assuming as many of them as you like won't in any way help you to find a reason), it is obvious that the reason must be found elsewhere…in something extramundane, different from the chain of states, or from the series of things, the collection of which constitutes the world.[2]

1. It is somewhat ironic that one of these principles, the so-called principle of least or stationary action, actually has conceptual roots in Leibnizian physics and metaphysics. Terekhovich (2018) has accordingly offered a modal interpretation of this principle that draws upon Leibniz's concept of essences or possibles striving for existence. Our own application of the principle does not rely on a modal interpretation or on Leibniz's concept, but it does require, in agreement with the dynamical character of Leibnizian physics, that the principle be acknowledged as a genuine dynamical principle, one that specifies the general nature of real physical force or action, and as such makes possible genuine explanations of physical phenomena. This realist viewpoint contrasts with the instrumentalist view of the principle as a mere mathematical tool that aids the construction and analysis of physical theories, but does not afford explanations.

2. Leibniz (1989: 149-150).

As for the case of a non-eternal world, of a universe that has not always existed, Leibniz does not explicitly consider it in his essay, presumably because he thought it obvious that such a universe stands in need of an extramundane origin. For he evidently excludes the possibility of it having arisen from nothing, since "existing things cannot derive from anything but existing things".[3]

Leibniz concentrates, therefore, on the case of a universe that has no beginning in time, and in doing so poses a challenge to those who seek to evade the possibility of an extramundane origin by positing an endless temporal (and causal) sequence of immanent things or states that stretches into the infinite past. The rationale here is, of course, that if such things or states only ever originate in earlier things or states of the same sort, then no other kind of origin is required. But Leibniz counters that this approach begs the question in regard to the entire sequence of states: explaining individual states in terms of earlier ones does not explain why the sequence itself exists, why there are such states in the first place, and thus why there is something rather than nothing at all. Therefore, even in the case of an eternal universe, one must, it seems, have recourse to an extramundane origin.

Furthermore, none of the developments in cosmology since Leibniz's time appear to have undermined his challenge. In particular, none of the cosmological models or theories that go beyond the known universe or posit a time before the Big Bang — such as cyclical cosmology, with its endless sequence of alternating expansions and contractions, or the multiverse as generated perhaps by a process of eternal inflation — have undermined it. For Leibniz's argument extends with impunity to the temporally larger domains considered in these schemes. Accordingly, we shall in the remainder of this article take the words 'universe' and 'world' to apply synonymously to temporal reality in general rather than to a proper temporal part thereof. In this way, we shall avoid any ambiguity over usage of these words as to their temporal scope.

3. Ibid., 152.

There is, however, another issue concerning scope that needs to be addressed here. For whereas the above-mentioned cosmological schemes apply only to the universe as something physical or in its physical aspect, temporal reality has not been unanimously identified with physical reality. Some philosophers, for instance, have held the universe to consist partly of mental or immaterial entities that exist independently of physical entities. Others, including Leibniz himself, have maintained that the universe consists ultimately of immaterial entities alone (minds, souls, monads), and that physical entities are only "ideas" or sensations or well-founded phenomena.[4] Therefore, in arguing that dynamical theory enables us to explain the existence and general character of the universe, we would, it seems, need to clarify beforehand not only the temporal scope of the word 'universe', but also its ontological scope.

That such a prior clarification of ontological scope is not in fact necessary, however, follows from the nature of our argument, which involves demonstrating that matter contains its own merely physical ground. For such a demonstration, if sound, would undermine any ontology according to which matter is dependent on or derived from something immaterial, including idealism in its various forms. It would also undermine property dualism or dual aspect theory, which holds that matter (or materiality) is only an attribute; for anything that contains its own ground, and thereby exists independently, should rather be deemed substance than attribute. Finally, even substance dualism would be undermined, if, in the course of our argument, we were to show (as we intend) that this physical ground of material being also constitutes the sole ground of material motion. For substance dualism requires some material motions to have an immaterial origin, whereas our dynamical argument, by explaining the existence of motion in a merely physical way, would rule out this possibility.

4. Garber (1985) has argued that Leibniz adopted his monadological metaphysics only after the 1690s, and thus only after he wrote his classic 1697 paper on the origination of things. So far as the present enquiry is concerned, however, nothing hangs on the truth or falsehood of Garber's claim.

In following this line of reasoning, then, it is evident why we do not after all need to specify in advance the ontological scope of the word 'universe'. For if we are successful in our endeavour, the fundamentally material constitution of the universe, of temporal reality in general, will emerge as a by-product of our argument, the other serious ontological contenders having been eliminated along the way. In this case, our explanation of the existence of matter will automatically constitute an explanation of the existence of the universe as such.

As to the general character of the universe — why it is the way it is — it is obvious that the explanation here is to be found in that very same entity which constitutes the ultimate origin of the things. Thus, whereas Leibniz takes the character of the universe to derive from the metaphysical and moral perfection of an extramundane being, we shall take it to derive from a certain "geometrical" perfection of matter's own purely physical ground, the details of which will become clearer as we proceed.

## 2. Primitive and Derived Matter

Before getting underway, it is necessary to consider briefly what appears to be a third possibility concerning material existence, in addition to those scenarios where matter has either an immaterial or a merely physical ground. For it might be that matter has no ground at all, that it is a primitive rather than derived entity, and as such does not require any explanation.

Indeed, a great many philosophers, past and present, have deemed matter to be primitive, and not all of them have been hard-headed materialists. Dualists like Anaxagoras and Plato, for instance, are in this camp. For the intellectual principles they posited are related to matter not as creators to created things, but as artisans or artists to works of art. Thus, Anaxagoras's Mind and Plato's Demiurge act upon a formless or chaotic but already existing matter, bringing to it definition and order but without adding to or subtracting from its original quantity. Such cases highlight a difficulty with the question 'Why does matter exist?' that arises in the very asking of it: the question assumes, or seems to assume, that matter is such that it stands in need of an explanation — an assumption that may well be false.

Despite this difficulty, and despite the long tradition of philosophers, materialist and otherwise, who have considered matter a fundamental constituent of reality, Leibniz surely has a point when he observes that there seems to be nothing in matter or the universe (as he conceives it) that assures us of its primitive or unconditioned character. For we find there, he says, only "physical or hypothetical necessity, which determines the later things in the world from the earlier", whereas in order to be convinced that we have reached rock bottom ontologically speaking, we require not hypothetical but "absolute or metaphysical necessity", where the existence of a thing depends not on other things but follows from its essence, from its own nature.[5] In the absence of knowledge about metaphysical necessity of this sort — whether there is any, and whether it belongs to matter or something else — the question of matter's ontological status would seem to be undecidable.

Perhaps the most that could be done in that case would be to argue that there is no convincing empirical or scientific evidence that matter is not primitive. But while this strategy might appear to be satisfactory from an epistemological point of view, a lingering doubt would remain. For want of evidence here does not *assure* us that matter is primitive. It assures us only that belief in the contrary state of affairs lacks warrant. On the other hand, a positive demonstration that matter derives from something else would dispel all controversy.

In what follows, we shall attempt such a demonstration. We shall argue, in the first place, that there is after all evidence, and good scientific evidence no less, that matter is a derived rather than a primitive entity. But we shall also argue, contrary to Leibniz, that that from which matter is derived consists not of some kind of immaterial or spiritual power, with which physics does not deal, but only of matter's own inner and purely physical force, the nature of which is represented symbolically by the principles of dynamics. From this

5. Leibniz (1989: 150).

result, we shall infer that matter is itself a locus of metaphysical necessity,[6] that it contains the reason for its existence within itself, thereby precluding an extramundane origin both of it and ultimately of all things that depend on it.[7]

### 3. How to Explain the Existence of Matter

We begin our treatment by clarifying further just what is involved in explaining the existence of matter, as well as what is not involved, for it is easy to go astray here.

There are two possibilities to consider: either matter has always existed or it began to exist at some point. But if it began to exist at some point, and if, as Leibniz supposed, existing things cannot derive from anything but existing things, then matter can only have derived from something immaterial. Why, however, should we accept Leibniz's supposition here? Why could not some existing thing, such as matter, have come from nothing?

Of course, it seems prima facie preposterous that it might have, for this would just mean that the existing thing in question has come into being without any cause, that it has simply popped into existence ungenerated. And if material things could come and go in that fashion, irrespective of the presence or absence of anything else, there would be no rhyme nor reason to Nature but only a rhapsody of phenomena, a wholesale confusion, as Lucretius has so colorfully depicted,[8] contrary to both untutored experience and methodical scientific enquiry.

Accordingly, scientific explanations always involve accounting for something in terms of something: the present state of a physical system in terms of an earlier state, the evolution of life in terms of genetic mutations and environmental pressures. This obtains even in quantum theory, which has a statistical aspect that seems to allow for spontaneous occurrences, and so might appear to give credence to the notion that matter itself is a spontaneous occurrence. While, however, this statistical aspect does indeed imply a certain looseness or indeterminism in the observed behavior of quantum systems, such looseness never involves a coming-into-being from nothing whatsoever. For there is always something physical already in existence on which the behavior is predicated, namely, the quantum systems themselves. Thus, in radioactive decay, unstable atoms constitute the already existing systems; in the pair production of elementary particles, there are underlying quantum fields. Extrapolating, then, from such examples to matter in general, it is clear why quantum statistics furnishes no warrant for the idea that matter has come into being from nothing.

Other, more positive reasons for rejecting this idea include the conservation laws of physics and the materiality of time. The conservation laws, which imply that the total amount of matter in existence does not change over time, appear to contradict the thesis that matter came into being at some point. For if matter did indeed begin to exist, there would, prior to the moment of its beginning, exist an empty time, that is, a time without matter, implying that a change in the total quantity of existing matter had occurred at that moment, contrary to the conservation laws. This argument assumes, of course, that time is not itself material, whereas general relativity seems to indicate the contrary, insofar as it identifies the geometry of space and time, taken together, with a material entity, the gravitational field.

6. Nolan (2011) has noted the variety in usage of 'metaphysical necessity' in contemporary fundamental enquiry. Although we adhere in this article to Leibniz's usage, our application of the term to matter ends up being rather Kripkean, insofar as the establishment of metaphysical necessity in this case is not a purely a priori affair, akin to the ontological argument for God's existence, but depends on principles that have proved their worth as elements of empirically successful theories of matter — even if these principles are, in themselves, among the most rational (i.e., least empirical) of all physical principles.

7. Strictly speaking, our result does not preclude things that exist beyond or "outside" the material world, that is to say, independently of matter. It only precludes them from constituting the origin of material things and their motions — though one might well ask in that case what the point would be of positing such inconsequential transcendent beings, and what warrant there could be for believing in them.

8. Lucretius (1997: 7-11).

Were we to assert, then, that matter began to exist at some point, we would also have to assert that time began to exist then, which implies that there was a time when time was not, a manifest absurdity.[9]

Thus, there are good scientific as well as good philosophical reasons for discounting the possibility that matter has come into being from nothing. Indeed, the reasons adduced above urge us very strongly toward the view that matter has not come into being at all, but has always existed. This, at any rate, is the scenario that Leibniz considers in his essay, and which we shall pursue here.[10]

Evidently, since explaining the existence of matter in this case cannot involve showing how matter came into existence, it can only involve showing how it continually exists, or persists in its being. Yet the idea of explaining the absolute persistence of matter might seem a bit odd. For do not scientific explanations always involve accounting for things in terms of antecedent causes, that is, by way of other things that are prior to them in time? And clearly, if matter has always existed, there could not have been anything which existed before it did.

It turns out, however, that not all explanations in natural science — perhaps not even the majority — involve the explanation of things or states or phenomena in terms of *earlier* things or states or phenomena. The motions of the planets, for instance, or electrical conductivity or eye color are none of them explained in this efficient-causal manner, but in terms of concurrent, underlying causes. In this way, too, are all material compounds explained in terms of the chemical elements, all chemical elements in terms of their atomic constituents, and all atoms in terms of the subatomic entities that compose them.

Therefore, when Leibniz, in addressing his reader or imaginary opponent, writes, "you assume only a succession of states",[11] we find ourselves unable to concur. For in addition to the temporal order of succession, we assume an atemporal or ontological order of composition, and without in any way leaving material nature. In other words, we consider material nature to have ontological depth, which opens up the possibility of matter containing its own ground. Furthermore, it is obvious that only in terms of physical causes that are ontologically rather than temporally prior could the existence of eternal matter be explained in a scientific way.

Yet here, too, a difficulty arises. For however far we descend in the ontological order of composition, we always seem to end up with material objects of some sort — objects which are, for the time being anyway, unexplained. Thus, if the material objects currently held to compose the atom were someday adequately explained in terms of still more fundamental objects, such as supersymmetric strings, the explanation provided would not explain the more fundamental objects themselves, leaving us bereft of the very thing we seek: an explanation of matter in general. Nor, obviously, could this difficulty be overcome by positing a bottomless hierarchy of material objects, for then we would be faced with an ontological analog of Leibniz's infinite temporal sequence of states, none of which explains the whole.[12]

9. Demonstrations, such as that in Hawking and Ellis (1973: 356-359), of an initial cosmic singularity, might seem to be at odds with this conclusion. However, this and other non-coordinate space-time singularities in models of general relativity theory physicists do not usually interpret realistically as denoting actual features of the universe, but only pathologically as indicating where the theory becomes inapplicable or "breaks down" and requires revision. See, for example, Wald (1984: 212, 241).

10. The other side of Kant's first antinomy, that the universe, and thus matter, must have a temporal beginning, otherwise something apparently impossible — the traversal of an actual infinity of states or temporal moments — would have occurred, has been the subject of some discussion lately (Puryear (2014), Ter Ern Loke (2016), Dumsday (2016)). Aristotle (1934: vol. II, 181), having denied that time consists of moments, was able to affirm the eternity of the universe without encountering this problem. As for the finitist view, it suffers from a serious difficulty of its own. For it seems to imply, as Kant (1996: 458-461) pointed out, the existence of an empty time prior to the world of things; and if Einstein (1982: 375) is right, no time can be empty, just because time and space are inseparable and no space-time can be empty, that is, exist independently of field.

11. Leibniz (1989: 149).

12. Leibniz himself actually posited a bottomless hierarchy in matter, as Schaffer (2003: 499) has noted. But whereas Schaffer champions brute ontological infinitism in materialist metaphysics as a serious rival to foundationalism (in its various forms), Leibniz appears, in his mature philosophy at least, to have taken the infinite ontological regression in matter to be explicable in terms of

But if explaining material objects in terms of other material objects is unsatisfactory for our purpose, as it clearly is, perhaps we could try explaining them in terms of physical entities of a different kind. After all, physics concerns itself not only with material objects but also with physical forces, of which dynamics is the general theory. Our next task, then, is to consider whether the existence of material things in general, or matter as such, can be explained by using dynamical principles.

## 4. The Role of Dynamics

But why would we even think that dynamical principles have anything to do with the existence of matter? For dynamics, as traditionally defined, is the theory of physical force insofar as it produces or changes material *motion*. There is no mention in this definition of material *existence*. Yet it is obvious to anyone who has more than a passing acquaintance with physics that dynamics is relevant to existential questions. For in the hierarchy of material composition discussed in the previous section — consisting of material compounds, chemical elements, atoms, and so forth — entities existing at higher levels are not for the most part simple aggregates of their lower-level constituents but result from a binding together or coupling of the latter through the agency of physical forces, including those forces responsible for motion.[13] To the extent, then, that the existence of higher forms of matter depends on such forces, it follows that dynamics is concerned with material existence as well as with material motion.

It is one thing, of course, to use dynamical theory to explain higher forms of matter in terms of lower forms, and quite another to explain matter in general with the theory. For those material forms that are at any given time deemed to be lowest or elemental will not themselves be explicable by means of a dynamical coupling of constituents, since they are invariably treated as simple entities, as beings without constituents — even if in some cases, as in string theory, they do not always seem to behave like simples, [14] or, as in the ancient atomism, they consist of inseparable parts.[15] Nevertheless, it will appear over the next two sections that a certain analogy obtains between explanations of material motion and explanations of material existence that points to the way in which dynamics can after all be employed to explain matter as such. In brief, just as dynamics can be used to account for the existence of motion in general as well as the existence or character of individual motions, so, too, can dynamics be used to account for the existence of matter in general as well as the existence of specific forms of matter.

It is already clear, however, that the kind of dynamical theory that is able to explain the existence of matter will not be mechanistic in character. That is, the forces which the theory posits will not be solely or principally of the mechanical type. For by 'mechanical force', we mean relational or other-determining force, force through which one thing (the body acting) determines another thing (the body acted on),

something transcendent (the monads), just as he took the infinite temporal regression in cosmology to be explicable in terms of something transcendent (God). For clarification of this important point, see Puryear (2020: 360-365). (I am indebted to an anonymous referee for this observation and the supporting reference.) As for recent discussions of foundationalism, including Schaffer's, it is typical that only material particles or physical properties are considered as candidates for the ultimately real, while agents or forces are left out of contention. Our view, however, is that forces are fundamental. And if Jorati (2019) is right, this was also Leibniz's view, the difference being that our primitive forces are physical, whereas Leibniz's were immaterial or spiritual.

13. van Inwagen (1990) has disputed this standard scientific view of material composition, arguing that all inanimate things except for elementary material particles are just aggregates or "arrangements" after all and thus not objects proper, unlike living beings. While, however, Newton's mechanistic dynamics appears to support van Inwagen here, insofar as it conceives the actions of material composites as mere sums or products of their ultimate material constituents' actions — due to the posited inertial and mechanical forces being merely additive — this does not obtain in the post-Newtonian non-mechanistic dynamics with which this article is concerned. Here, on the contrary, physical force is not additive (Gunn (2013: 194-195)), from which it follows that at least some inanimate material composites (hydrogen atoms, for instance, but not heaps of sand) are dynamically irreducible to their constituents — which in turn opens the door to natural kinds.

14. Baker (2016).

15. Lucretius (1997: 20).

such as percussive force or Newtonian centripetal force;[16] and it is obvious that force of this merely relational kind presupposes matter, and as such is ontologically posterior to matter. Therefore, even if mechanical-type forces can be invoked to explain how material composites come to exist from material simples, they obviously cannot be invoked to explain the existence of the material simples themselves. Consequently, they cannot be called upon to explain matter in general or as such.

A different kind of force, then, is required for this purpose. But only one other kind of force besides mechanical force is conceivable. For if the latter is other-determining force, that leaves self-determining force as the sole remaining possibility. Since, however, there is no ready-made generic term in physics for this kind of force, let us call it *pneumatical force* in view of the fact that the Greek word *pneuma* and its derivatives have in philosophical and theological contexts always referred to powers of self-determination,[17] irrespective of whether these powers were deemed to be physical or spiritual in nature — although in this paper, of course, we are concerned only with self-determining powers that are physical.

16. The term 'mechanical force' is sometimes restricted to contact forces. But here, we apply the term to all other-determining forces. Einstein and Infeld (1966: 10-11) likewise held the mechanical viewpoint to admit other-determining forces of the non-contact type.

17. The word *pneuma* literally means a blowing or breath. Its "first extant use", according to Kirk, Raven, and Schofield (1983: 158-160) was made in the sixth century BC by the Greek philosopher Anaximenes, for whom it signified Air, the supposed material principle of all things. Anaximenes conceived Air in its cosmic capacity as a kind of world breath or world soul, by which the universe holds itself together and maintains itself. The term was later employed by the Stoics in a similar way, with the important addition that the power it denoted was deemed the immediate origin of all rationality. Much later, in the seventeenth and early eighteenth centuries, 'pneumatology' signified that branch of metaphysics concerned with spiritual entities, and later still denoted rational psychology, an a priori science of the mind. (See, for example, Hegel (1971: 2-3) or the "pneumatology" entry in Flew (1984)). What these varied applications have in common, however, is that in every case, powers of self-determination (or theories about such) are denoted, which is why we have in this article chosen the word 'pneumatical' to be the opposite of 'mechanical'.

Pneumatical force, being non-relational or only reflexively relational, arises from within material things not between them, in contrast to mechanical force. As such, pneumatical force, unlike its mechanical counterpart, is not necessarily ontologically posterior to matter: it may be ontologically coexistent with matter, or it may even be ontologically prior to such, which is obviously what is required if dynamics is to account for matter's existence.

Classical physics identifies at least two pneumatical powers: Newtonian inertial force, which (unlike mechanical force) acts not to change but to preserve a body's state of motion; and Leibnizian living force, an original power of self-motion in bodies. Neither of these pneumatical powers are, however, up to the task of explaining the existence of matter, on account of their purely kinetic character. That is, even if the powers are deemed to be innate to and thus constitutive of matter, these powers do not, through their action, actually produce matter, since they are merely powers of self-motion. As such, they are only ontologically coexistent with matter, not ontologically prior to it.

The kind of pneumatical force we are seeking, on the other hand, is required to be not only a power of self-motion but also a power of self-generation, and as such must constitute an internal source of material being as well as of material motion. Of course, the very idea of self-generation, or of that which causes itself, might seem to be an impossible one. For how could something (e.g., matter) that does not already exist be a cause or origin of anything? And if it does already exist, how could it then bring itself into existence? The simple answer is: "It couldn't". Unless, that is, it happens to be eternal, in which case it might continually bring itself into existence in the sense of persisting through its own power. Our central claim in this article is that dynamical theory has now progressed to a point where it comprehends such a power of self-generation in matter.

## 5. The Dynamical Explanation of Motion

Although this article has primarily to do with explaining the existence of matter rather than the existence of motion, there is, as we mentioned in the previous section, an important analogy between the two that points us toward the correct explanation of material existence. Furthermore, a dynamical and thus purely physical explanation of the existence of motion would undermine substance dualism, as per our remarks in Section 1, and thereby permit us to take our dynamical explanation of the existence of matter to be also a dynamical explanation of the existence of the universe as such. Finally, since the dynamical explanation of motion is the easier explanation to grasp, appearing as it does even in Newtonian dynamics, it allows us to introduce in a relatively straightforward way the key ideas that are needed to appreciate the dynamical explanation of matter, which depends on resources from post-Newtonian physics. Let us therefore begin with the easier case and proceed to the more difficult.

The first thing to observe is that Newtonian dynamics is an instance of mechanistic dynamics. And while, as we pointed out, a dynamics of this type is unable to explain the existence of matter, it *is* capable of explaining the existence of motion, because motion, unlike matter, is not prior to mechanical force. At least, that is true of Newtonian centripetal force, which acts even when bodies are not in contact with one another and not moving relatively to one another. On the other hand, in the case of primitive contact forces (assuming, for the moment, that such forces exist), it is manifestly untrue. For here, mechanical force arises only with the pressing of one body upon another, resulting either from a collision, which requires a prior relative motion of the two bodies, or, in the context of a mechanical medium, from a motion pre-existing in the whole. Either way, motion is prior to mechanical force in this case, and so cannot be explained by the latter.

Consequently, non-dynamical theories of matter, such as those of the ancient atomists and Descartes, who conceived matter as inert and so allowed that bodies can affect one another only by contact, are unable to afford a physical explanation of the existence of motion. Descartes, accordingly, explained its existence in terms of an extramundane being.[18] There is, however, no need for us to bother with such non-dynamical theories, in view of their gross empirical inadequacy. Nor will contact forces more generally give us any trouble, provided that they are understood in the way that physicists today generally understand them: as forces that are not primitive, but derived from non-contact forces.

The Newtonian dynamical explanation of the existence of motion, then, runs as follows. First, we stipulate, as we did with matter, that to explain the existence of motion is to explain not how it came into existence, but how it persists or continues to exist. In Newtonian physics, the persistence of motion is expressed by the laws for the conservation of the total quantity of momentum, where linear momentum is just the product of mass and velocity, while angular momentum is (in the simplest case) the product of linear momentum and the distance from a point or axis. What we are seeking, therefore, is to explain these laws in terms of Newtonian impressed or mechanical force. This turns out to be very easy for linear momentum, since its conservation follows directly from Newton's Second and Third Laws of Motion. For angular momentum, the explanation likewise follows from these laws but is more involved,[19] so we shall only consider the linear case here.

Newton's Second Law of Motion states that the change in the linear momentum of a body is proportional to the force impressed upon it, while his Third Law states that for every impressed force, there is another force of this kind which is equal in magnitude but opposite in direction to the first. It follows that the change in momentum induced by the first force is equal in magnitude but opposite in sign to the change in momentum induced by its reciprocal complement (and so on for every pair of reciprocal impressed forces). In other words, these two changes exactly counterbalance one another, so that there is no overall change in linear momentum. The total quantity of rectilinear motion is therefore conserved, which is what we set out to

18. Descartes (1985: vol. I, 240).

19. Goldstein (1980: 6-7).

show. An analogous dynamical argument holds for curvilinear motion. That dynamics enables us to explain the conservation of the total quantity of motion in a merely physical way implies that there could be no immaterial contribution to this quantity, contrary to substance dualism.[20]

Evidently, the decisive factor in this dynamical explanation of motion is the reciprocal nature of mechanical force as expressed in Newton's Third Law of Motion. That is, the existence (i.e., persistence) of motion has been explained in terms of the reciprocal action of such force. We shall see later that something similar obtains in the dynamical explanation of matter, although it is clear that the analogy will not be exact. For the notion of reciprocal action only makes sense in the case of mechanical force, which is other-determining or relational, whereas pneumatical force, which is required for the explanation of matter, is self-determining force. As such, it cannot have a reciprocal complement. What we need to notice, therefore, is that reciprocal action is a kind of *symmetric* action: a mechanical force and its reciprocal complement, being equal and opposite to each other, are, so to speak, mirror images of each other. They, or rather their vector measures, exhibit reflection symmetry, and in dynamics, this kind of symmetry implies another, which pertains not only to mechanical but also to pneumatical force.

Specifically, the reciprocity of Newtonian mechanical force implies that such force cannot depend on the positions of bodies, but only, at most, on their differences in position, that is, on their distances from one another. For if the force's magnitude depended merely on their positions, reciprocity would not in general obtain, given that interacting bodies always occupy different positions from one another. Accordingly, Newtonian gravitational force is independent of position: its strength depends only on the inverse square of the distances between bodies.

Now, this position-independence of mechanical force constitutes an invariance or symmetry of the force, but a different kind of symmetry from the reciprocity of mechanical force. In the first place, it is not a reflection symmetry but a translation symmetry: it signifies that transporting a system of interacting bodies to any other location in space would not affect the strength of the forces acting. These forces are therefore said to be symmetric or invariant under space translations. But this symmetry is, in the second place, *internal*[21] in the sense that it obtains for each individual instance of the force, whereas reciprocity only ever applies to pairs of forces: to a mechanical force and its reciprocal complement. Thus, internal symmetry is what carries over to pneumatical force, and so it is this kind of symmetry which, in post-Newtonian physics, enables us to furnish a dynamical explanation not only of the existence of motion but also of the existence of that which moves, namely, of matter itself.

### 6. The Dynamical Explanation of Matter

The first step in the dynamical explanation of material existence is to identify the conservation laws to be explained and the dynamical principles to be used in explaining them.

The conservation laws are just those for electrical charge, the weak isospin and color charges of nuclear physics, and gravitational charge or energy. For these conserved quantities are not merely kinetic, like linear and angular momentum, but "substantial", and as such, constitute the material sources of the four fundamental kinds

20. In his recent defence of substance dualism, Swinburne (2013: 112-115) attempts to circumvent conservation arguments from classical physics by claiming that in quantum physics, Heisenberg's Uncertainty Principle implies that the conservation laws hold not strictly but only statistically. However, as we shall indicate, analogous theoretical demonstrations showing that the conservation laws hold strictly also in modern field theories, including those of quantum physics, reveal that Swinburne is mistaken on this point. Heisenberg's Uncertainty Principle pertains to the appearance or measurement of physical things, as Swinburne acknowledges, but if the uncertainties it denotes are to make room for the interaction between material and immaterial substance that he envisages, they really need to pertain to physical things as they exist in themselves, something that the conservation laws, strictly obtaining, and the deterministic evolution of the wave function preclude.

21. This usage of 'internal' is distinct from the usage that denotes field or gauge symmetries as opposed to space-time symmetries.

of physical coupling upon which all the higher properties of matter depend. If it can be shown that the conservation of these quantities is explicable in terms of the properties of physical force, a dynamical and thus entirely naturalistic explanation of the existence of matter will have been afforded.

The dynamical principles from which the conservation laws of physical charge are to be derived consist, as in the Newtonian mechanical explanation of the conservation of motion, of (1) a general law of physical force or action, analogous to Newton's Second Law of Motion, and (2) specific dynamical laws that constrain the forces acting to be symmetric, analogous to Newton's Third Law of Motion — or, more correctly, to the space-translation and rotational invariances implied by that law. The general dynamical law in this case differs, however, from its Newtonian counterpart in two ways. For it is, and must be, a pneumatical rather than a mechanical law, as we have already determined, and it must also be applicable to physical fields, since all of the modern fundamental theories of matter are, at bottom, field theories, not particle theories.[22]

These two requirements imply that the mathematical form of our general dynamical principle will satisfy certain conditions. *First*, the mathematical measure of physical force or action appearing in the principle will, like the measures of inertial force and living force, be a scalar rather than a vector quantity. For a vector force measure, in pointing from the thing acting to the thing acted upon, is "directional" and thus appropriate to other-determining or mechanical force, whereas pneumatical force is by definition a power of self-determination. Therefore, only a scalar measure, which has a magnitude but no direction, will do. *Second*, the principle will not be restricted to dynamical variables of the form $\mathbf{x}(t)$, which denote the trajectories of material particles, but will also (or rather) be expressible in terms of dynamical variables of the form $\psi(t,\mathbf{x})$, which represent the configurations of physical fields.

There is, however, one further condition that our dynamical principle must satisfy. Like Newton's Second Law of Motion, it has to pertain not only to the motion of material things but also to their coupling, given that physical charge, the persistence of which we are here seeking to explain, constitutes the source of the latter. Therefore, the pneumatical action measure appearing in our dynamical principle will not be purely kinetic (like the measure of Leibnizian living force), but be such that it can admit coupling terms as well as kinetic terms.

The general dynamical principle that satisfies these three conditions and applies to all of the fields in modern fundamental physics, fermionic and bosonic, including the gravitational field of general relativity theory, is Hamilton's Principle of Stationary Action.[23] This principle, which is the modern counterpart of Newton's Second Law of Motion, states that physical systems evolve in a such a way that the first-order variation of a certain dynamical quantity, their action, vanishes. The action measure $S$, a scalar quantity, is an integral

22. The question of whether quantum field theories should be accorded a particle or a field interpretation remains contentious (Deckert, Esfeld, and Oldofredi (2019), Bigaj (2018)). What is less debatable, if indeed it is questionable at all, is the fact that the dynamical variables of the theory are field variables rather than particle variables, which is the sole fact of relevance to our argument.

23. Hamilton's Principle, as previously noted, we consider to be a genuine dynamical principle — one that denotes the action of real physical power — and this enables us to use it to explain the existence of matter and motion. Katzav (2004: 212) asks: "Why are the deductions that the [principle] affords explanatory?" They are so because a power is by definition that which generates things or effects change, and such are precisely what one seeks to explain in natural science. Katzav, to be sure, argues that the action principle conflicts with the view that there are elementary powers in the world. But the kind of powers he has in mind are those of dispositionalism or dispositional essentialism, powers that are "not wholly manifest in the present" and become manifest "in response to appropriate prompting" (2004: 206), whereas the power denoted by Hamiltonian "action" cannot be of this sort due to the atemporal and universal character of its principle. Our interpretation of the action principle as a genuine dynamical principle is motivated by its conceptual provenance in Newtonian and Leibnizian dynamics, and by the fact that it stands to modern physical theories just as Newton's dynamical principles do to the theories of classical physics, as a general principle of physical action that constitutes the formal framework of more determinate dynamical laws — one that likewise makes possible an explanation of certain fundamental conservation laws. Some commentators have, admittedly, argued that Newton himself was not a realist about physical force, but see Janiak (2007) for a contrary view.

over kinetic terms and coupling terms that take on different forms corresponding to the different particles or fields to which the principle is applied,[24] just as the Newtonian mechanical force measure **F** in Newton's Second Law of Motion takes on different forms for different mechanical systems. But Hamilton's Principle itself — the stationary character of the action, the vanishing of its first-order variation — is the same for all applications. From this vanishing condition, a physical system's equations of motion are easily derived.[25]

In order, however, to derive and thereby explain the conservation of physical charge, we require not only stationary action but also symmetric action.[26] Just as the conservation of linear momentum in Newtonian physics is derived from the space-translation invariance of Newtonian mechanical force, so the conservation of the different fundamental charges in modern field theory are derived from invariances of the action measure in Hamilton's Principle. Unlike space-translation invariance, however, which involves continuous global[27] transformations of the spatial co-ordinates $\mathbf{x}_i(t)$, three of these invariances or symmetries are gauge or field symmetries. That is, they involve continuous global transformations of the field variables $\psi_i(t,\mathbf{x})$, where the transformation operators belong to the unitary groups U(1), SU(2), and SU(3). The symmetries or invariances of Hamiltonian action under these three kinds of transformation yield the conservation laws for the electrical, weak nuclear, and strong nuclear charges respectively, *provided* that the action is also stationary.[28] As for gravitational charge or energy, its conservation follows analogously from the time-translation invariance of Hamiltonian action.[29]

But how, exactly, do these continuous symmetries of Hamiltonian action lead to the conservation of the four fundamental physical charges? In each case, the symmetry transformation that is to leave the action measure unchanged is applied to the boundary or endpoints of the physical system's path (in configuration space) for which the action measure has a stationary value. Normally, that is, when deriving the conditions under which Hamilton's Principle obtains, these endpoints are not varied but are held fixed while the path is varied, and the resulting conditions are a set of equations of motion for the fields involved. But in the present case, where the endpoints are varied and the path is then specified to be the stationary one, different conditions appear in the form of quantities that are time-constants of the motion, that is, conserved quantities, one for each of the continuous symmetry transformations applied. This shows that if a physical system's action is not only stationary but also continuously symmetric, then there is a conserved quantity corresponding to that symmetry, as

24. Hamilton (1940: vol. 2, 160, 167). In quantum theory, for instance, these terms involve not the ordinary-number variables of classical physics that Hamilton himself used, but operator variables. See, for example, Yourgrau and Mandelstam (1968: 139) or Schwinger (1951: Section II).

25. Goldstein (1980: 43-45, 548-552).

26. Our claim that symmetries of a certain sort are fundamental in nature, and thus explain the existence of material things, runs counter to some recently expressed views on the matter. McKenzie (2014), for instance, doubts that symmetries are ontologically prior to material objects on the ground that it is unclear how to comprehend them as genuinely physical independently of such objects. We contend, however, that this is possible if one takes them to be properties of physical force of the pneumatical type. Comprehending symmetries in this dynamical way also meets the objection posed by Romero-Maltrana (2015) and Brown and Holland (2004), that since one can derive the symmetries of the action from the conservation laws as well as the converse, no arrow of explanation can be inferred. Yet the action concept itself must be given prior to any derivation of the symmetries of action, and this concept, we maintain, is no mere mathematical construct, but denotes real physical force, and of such a type that can explain but not, in turn, be explained by the conservation of physical charge. Romero-Maltrana (2015: 366) asserts the converse, that "conserved charges explain forces", and he is in a way correct if by "forces" he means mechanical or other-determining forces. However, such forces, we maintain, are not ultimate but, like physical charge itself, ultimately derive from pneumatical force, and insofar are not real powers but at most only well-founded phenomena.

27. That is, transformations which are not functionally dependent on space-time coordinates.

28. Mandl and Shaw (2010: 221, 225-227, 391-395).

29. Goldstein (1980: 588), Ryder (1996: 85-88). In general relativity theory, energy conservation and its relationship to dynamical symmetry are rather more involved than this compact statement can convey. See, for example, Duerr (2019) and references therein.

Emmy Noether[30] was the first to demonstrate quite generally. All of this is rather technical, of course, even without our employing the corresponding mathematical symbolism, and so provides little by way of an intuitive grasp of the important results that Noether's Theorem affords. Therefore, let us now attempt a more intuitive justification of them.

Noether's Theorem shows that the fundamental conservation laws of physics can be explained dynamically in terms of the stationary, symmetric character of Hamiltonian action. The conservation laws specify what in matter and motion persists absolutely, what suffers no overall augmentation or diminution. However, the laws of stationary and symmetric action themselves express constancy of a sort, not as it obtains in matter as such, but as it obtains in physical force, and they do so in two ways, pertaining respectively to the exterior and interior of a physical system. Intuitively, there could be no guarantee of constancy in a physical system if (1) the pneumatical power governing it were determinable from without, as, for example, Newtonian inertial force and Leibnizian living force are (insofar as the bodies to which they belong are so determinable), or (2) the governing power were changeable in itself, making the system's laws of motion also changeable, and thus not laws strictly speaking. We therefore need to exclude these possibilities. Our principles of physical action and dynamical symmetry[31] exclude them as follows.

That the pneumatical power of which Hamiltonian action is the measure is not determinable from without follows from the measure's stationary character. For the principle of stationary action is, in effect, a generalization of Newton's First Law of Motion, as Whitehead (1929: 77) has observed — an extension, that is, of the notion of free or unconditioned material action from the isolated physical entities to which Newton's First Law applies to systems of physically coupled entities to which his Second Law applies.[32] The stationary or extremal path of a system of physically coupled entities in configuration space is the Hamiltonian analogue of the geodesic path in space-time of an inertially moving Newtonian particle. In the degenerate case of a system that consists of only one such particle, the latter's geodesic path is at the same time a path of stationary action. Accordingly, non-stationary paths in configuration space are the Hamiltonian analogs of non-geodesic paths in space-time, and so would, were they physically possible, signify determination from without.

Thus, 'stationary action' denotes physical force that is constant or unconditioned in the sense that there exists nothing external to the physical system it governs that conditions it, as it conditions the things within the system itself. [33] In this respect, stationary action is

30. Noether (1971).

31. Brown and Holland (2004: 1133) denote by 'variational symmetry' what we call 'dynamical symmetry', and reserve the latter term for "transformations which map solutions of the equations of motion…into solutions", while applying the former to symmetries of the Hamiltonian action, as if "action" were not a dynamical concept after all but only a mathematical one. Their usage may be in line with recent convention, but to our mind it would be more in accord with the etymology of 'dynamics', and with Leibniz's introduction of that term to physics, to apply it to principles and measures of physical force or action rather than to equations of motion, the symmetries of which might be better called "kinetic symmetries". In Newtonian physics, of course, dynamical symmetries and kinetic symmetries are identical, since Newton's dynamical principles are identical to his general laws of motion. But in the higher dynamics of Hamilton, this is not the case: the general laws of motion (Euler-Lagrange equations) are derivable from rather than identical to the principle of action.

32. Neither of Newton's laws apply to physical fields, of course, yet Hamilton's action principle does so, and it applies equally to free fields and to systems of coupled fields.

33. The difference between our own realist interpretation of the principle of stationary action and the modal one developed by Terekhovich (2018) comes into sharpest focus at this point. We regard Hamilton's action measure as the measure of a power that is not only real but also non-dispositional, with the stationary path alone having physical significance in denoting, as we say, a power that is free or unconditioned from without. Terekhovich, on the other hand, in accord with dispositional essentialism, takes the action measure to be a measure of physical essence that is realized, or made actual, only in certain cases, but where a "collision" or "competition" of possible paths, stationary and non-stationary, explains the actuality of the stationary path. We note also that Terekhovich takes inspiration from Feynman's path-integral formulation of quantum theory on the basis that both the action principle and the path integral contain the same action measure. Yet he makes no

akin to Aristotle's unmoved mover,[34] which it resembles even in name, although it surpasses Aristotle's absolute in constituting not only an unmoved origin of material motion but also an ungenerated origin of material being.

Yet stationary action is, as we have seen, not sufficient to guarantee constancy or persistence in a physical system. For while it excludes external sources of change, it does not do the same for the system's interior. In particular, it implies nothing at all in this regard about the *specific* dynamical law or laws that govern the system. And a system whose dynamical laws varied in character with time, place, motion, and so forth could hardly be one in which there is any continuity or persistence of the kind we are seeking, that is, with respect to its quantity of matter and motion. Therefore, we require not only stationary action but also continuously *symmetric* action. For such action is, by definition, invariant with respect to time, place, etc. It is, to speak non-technically, action that is in maximal agreement with itself. Thus, if stationary action is akin to Aristotle's unmoved mover, then symmetric action is akin to the Cartesian deity, not in being transcendent or immaterial, but insofar as it conserves the total quantity of matter and motion in the universe by "operating in a manner that is always utterly constant and immutable".[35]

To this extent, then, can we grasp intuitively why the conservation laws of physics, and thus the existence of matter and motion, are dynamically explicable in terms of the stationary and symmetric character of pneumatical or self-determining force.

These results from fundamental physics, which concern the relationship between dynamical symmetry and the conservation laws, have long been known. But they have not, so far as we can tell, been interpreted as we have interpreted them here, as results of existential significance. Noether's Theorem in particular, which embraces all of these results, is not generally understood in an ontological sense as an *existence theorem*, but only methodologically as furnishing an efficient procedure or algorithm for deducing from the symmetries of a physical system's action measure the corresponding conserved quantities, which can then be used to facilitate the solving of problems when applying theory to the phenomena.

One possible reason for this neglect is that discussions of Noether's Theorem and its applications are not normally preceded by a careful analysis of what it means to explain the existence of matter and motion, such as we have attempted here, and which has concluded that explaining their existence involves accounting not for their coming-to-be but for their continuing-to-be. Another possible reason is the prevailing yet anachronistic understanding of physical force as mechanical force, as something that arises between material things rather than from within them, making it impossible to grasp how such force could constitute the origin or ground of matter in particular. Yet a third reason might be that fundamental physics, and dynamics specifically, are generally (and rightly) regarded as incomplete, from which one might naturally conclude that any attempt at this stage to use dynamics to explain the existence of matter is premature.

Now, we agree that dynamics is incomplete insofar as physicists still acknowledge four fundamental couplings rather than one, as well as a number of different kinds of fundamental physical object (i.e., different kinds of field) rather than a single kind. In short, physicists have not yet obtained a fully unified theory that both explains our current fundamental theories and is adequate to all the relevant known phenomena. But this fact, in our view, concerns only the *specific content* of dynamics, the non-unified character of its action measure, whereas we have based our explanation for the existence of matter not on this content but on matter's general dynamical form as expressed by Hamilton's Principle of Stationary Action and a certain abstract and

mention of Schwinger's variational formulation, which contains not just the action measure (in operator form) but the action principle itself, and which is arguably more aligned with the classical understanding of the principle as denoting evolution along a single path than with the many-paths alternative he proposes (Schwinger (1951: Section II), Yourgrau and Mandelstam (1968: 138-139)).

34. Aristotle (1934: vol. II, 333-337).

35. Descartes (1985: vol. I, 240).

general result within Hamilton's dynamical scheme that concerns dynamical symmetry, namely, Noether's Theorem.

To be sure, we did not remain at the level of complete generality, but descended to particulars when we mentioned that the existence — that is, the persistence or continued existence — of the four fundamental kinds of physical charge currently acknowledged is explicable in terms of specific dynamical symmetries, namely, those pertaining to the actions of certain kinds of physical field. But this was only by way of illustration, to indicate that such results are obtainable in the context of physical theories of tremendous explanatory power. In themselves, Hamilton's Principle and Noether's Theorem are very general and abstract, and as such, quite independent of specific dynamical theories. There is no reason to expect, therefore, any future and more unified physics to abandon the dynamical and thus purely naturalistic explanation of matter and motion that they afford. Indeed, any such a step would surely be retrogressive.

## 7. Conclusion

Prompted by Leibniz's essay on the subject, and by certain developments in general dynamical theory, we have in this article enquired into the ultimate origination of things and considered the following possibilities: (1) that matter, eternal or otherwise, and consequently everything that depends on matter, have their ultimate origin in something extramundane or immaterial (this is Leibniz's view); (2) that matter is eternal but primitive, and as such, constitutes an origin of other things but has no origin or ground of its own; (3) that matter came into being from nothing; (4) that matter is eternal but has an immanent or merely physical origin.

In regard to (1), we agreed with Leibniz that even if the universe has always existed, this would not preclude an enquiry into its origins. But we disagreed that the viability of such an enquiry leads inevitably to the conclusion that the universe, and thus matter in particular, ultimately originated in something extramundane. For it might be that matter, although eternal, has ontological depth, and of such a kind that it contains its own ground, in which case it would exist independently.

As for (2), which has been accepted by many philosophers, we considered this a genuine possibility but one that relies for its plausibility on the following rather weak and, in our view, ultimately indefensible premise: that there is no good empirical or scientific warrant for thinking that matter is anything but a primitive or underived entity.

Concerning (3), we again sided with Leibniz in rejecting the idea that the universe, and thus matter, began to exist at some point without there being anything prior. We dismissed this idea on both philosophical and scientific grounds, including the conservation laws of physics and the materiality of time. The latter reasons, indeed, urged us toward the view that matter has always existed, and that a scientific explanation of it could therefore only involve accounting for its persistence or continued existence rather than its coming into being.

Option (4), which we have defended in this article, calls for such an explanation. Recognizing, first of all, that if matter is to have an immanent or physical origin, the latter could not, without question-begging, be held to consist of material objects. From this, we inferred that such an origin could consist only of material agency or physical force, the general theory of which is dynamics. It was also clear, however, that mechanistic dynamical principles, such as those of Newton, would be incapable of explaining the existence of matter, simply because mechanical force is relational or other-determining force, and as such, presupposes matter. Therefore, we required principles of pneumatical or self-determining force, and found suitable ones in Hamilton's Principle of Stationary Action and the symmetry principles of modern field theory. For physicists have long known that if the action measure appearing in Hamilton's Principle is both stationary and symmetric in certain ways, it is possible to deduce the conservation not only of kinetic quantities, like linear and angular momentum, but also of electrical, nuclear, and gravitational charge, and insofar explain the persistence of these fundamental and "substantial" physical quantities in dynamical terms.

From this result, which was anticipated and expressed in abstract form by the remarkable theorem of Emmy Noether, we now conclude that matter *as object* is not after all primitive or ontologically ultimate, yet contains its own ground, consisting of its own inner and purely physical force. In other words, matter *as agent* is a metaphysically necessary being, a being whose existence follows from its own dynamical essence — this being such (pneumatical, unconditioned, maximally self-agreeable) that matter cannot not exist.

But if the origin of matter is internal to it and merely physical besides, then transcendent or immaterial origins are ruled out, contrary to idealism. And if this origin is also the source of all material motion, as we have indicated, it cannot obtain that some material motions have an immaterial origin, contrary to substance dualism. And if, further, matter contains its own ground, and is thus an independently existing entity, it ought to be deemed substance rather than attribute, contrary to property dualism. From these results, we infer that the universe, or temporal reality in general, is fundamentally material in its constitution, and that the origin of its existence lies entirely within itself, contrary to Leibniz.

This brings us, finally, to the question of the general character of the universe that is conferred by its origin. Leibniz, we recall, held the universe to be incomplete, insofar as he deemed the reason for its existence to lie in something extramundane. Yet he also held it to be "the most admirable machine" and "the best republic",[36] owing to the metaphysical and moral perfection of its transcendent ground. In regard to the first point, we obviously cannot agree with Leibniz, since we hold the universe to contain its own ground and thus to be complete and sufficient unto itself, making it to that extent superior to the universe as he conceived it. As to the second point, we concede that, at the fundamental level at least, temporal reality exhibits a remarkable self-agreement that accords with the overall "harmony of the universe" that Leibniz speaks of.[37] For our part, however, this harmony owes not to the perfection of an extramundane being but to those immanent dynamical symmetries — from which the existence of matter and motion are derived — being perfect in the sense of continuous or maximal: in other words, being symmetries of the sort that led the ancient Greeks to revere the circle and the sphere as the most perfect of all geometrical objects.

36. Leibniz (1989: 153).

37. Ibid., 154.

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