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Does Physics Forbid Libertarian Freedom?

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Abstract: Three well-known physicists have recently argued that libertarian freedom is impossible. In their view, free will is incompatible with what we know about science at the most fundamental level. Here I show that their arguments presuppose a naïve version of reductionism and consider two alternatives, one appealing to mind–body dualism and the other to emergentism. The former says that free will is a capacity of one's mind, an immaterial entity not subject to the laws of nature. The latter says that free will is an emergent capacity that cannot be reduced to the properties of an agent's constitutive atoms. These alternatives, however, face the same problem: They seem to violate a fundamental law, namely the conservation of energy. I show how the libertarian can respond to this objection.

Keywords: libertarianism; free will; conservation of energy; dualism; emergentism

According to many physicists, the answer is "yes". Those in the public eye such as Sean Carroll,[1] Sabine Hossenfelder,[2] and Brian Greene[3] make this explicit. There simply is no room in physical reality for that sort of free will.[4]

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[1] See Sean Carroll, **The Big Picture: On the Origins of Life, Meaning, and the Universe Itself**, Dutton, New York 2016, p. 381.

[2] See Sabine Hossenfelder, "You Don't Have Free Will, but Don't Worry", *BackReAction* 2020, October 10, https://tiny.pl/9vkqr [23.10.2021].

[3] See Brian Greene, **Until the End of Time: Mind, Matter, and Our Search for Meaning in an Evolving Universe**, Alfred A. Knopf, New York 2020, p. 180.

[4] Libertarian freedom is usually considered the opposite of determinism. It is the intuitive sort

As Carroll puts it:

> There's no reason to accept libertarian freedom as part of the real world. There is no direct evidence for it, and it violates everything we know about the laws of nature. In order for libertarian freedom to exist, it would have to be possible for human beings to overcome the laws of physics just by thinking. [5]

Some will be puzzled by Carroll's claim, which sounds more at home in the nineteenth century than today. Hasn't modern science overthrown this sort of deterministic thinking? Didn't quantum mechanics break the grip of causal determinism, opening the way for a robust notion of freedom? Well, maybe. Quantum indeterminism has not escaped Carroll's notice. However, indeterministic interpretations of quantum mechanics are less dominant now, and determinism may regain its status within fundamental physics in the decades to come. The many-worlds interpretation — once a mere curiosity — continues to attract adherents both in physics and the philosophy of physics. [6] Libertarians should therefore not rest easy that science has cleared the path of obstacles for all time. And even if the *status quo* were to remain in place, libertarians realize that indeterminism is not sufficient for free will. Here I choose to make things as difficult as possible for libertarianism and assume that fundamental physics is deterministic.

In context, Carroll's claim is less about determinism than reduction. Like many

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of free will that almost everyone assumes that they have until philosophical or scientific objections are raised. Most libertarians believe that, whatever choices one does in fact make, there are alternative possibilities that one could have chosen. Moreover, the determining factor as to which choice is made lies within the volitional control of the agent. For more, see Kevin Timpe, **Free Will: Sourcehood and Its Alternatives**, 2nd ed., Continuum, New York 2012; Timothy O'Connor and Christopher Franklin, "Free Will", in: Edward N. Zalta (ed.), **The Stanford Encyclopedia of Philosophy**, Spring 2021 (Metaphysics Research Lab, Stanford University, 2021), sec. 2, https://tiny.pl/9vkqp [23.10.2021]; Derk Pereboom, **Free Will, Elements in Philosophy of Mind**, Cambridge University Press, Cambridge 2022, https://doi.org/10.1017/9781108982511.

[5] Carroll, **The Big Picture...**, p. 381.

[6] For the many-worlds interpretation, see Simon Saunders, "Many Worlds? An Introduction", in: Simon Saunders, Jonathan Barrett, Adrian Kent, and David Wallace (eds.), **Many Worlds?: Everett, Quantum Theory, and Reality**, Oxford University Press, Oxford 2010, pp. 1–49; David Wallace, **The Emergent Multiverse: Quantum Theory According to the Everett Interpretation**, Oxford University Press, Oxford 2012. The other well-known deterministic interpretation is Bohmian mechanics. See Sheldon Goldstein, "Bohmian Mechanics", in: Edward N. Zalta (ed.), **The Stanford Encyclopedia of Philosophy**, Summer 2017 (Metaphysics Research Lab, Stanford University, 2017), https://tiny.pl/9vkx7 [23.10.2021].

physicists, he takes the relation between mental states and brain states to be roughly the same as thermodynamics to statistical mechanics. That, then, is where we begin. We move on to two ways out of Carroll's reductionism, one appealing to substance dualism and the other emergent properties. While both are controversial, the most worrisome charge is that they suffer from the same flaw: they entail the violation of a fundamental law of nature, namely the conservation of energy. The main part of this paper shows why this is not the case. Conservation laws are conditional and when those conditions are not met, the law does not apply. Note that getting to the main topic requires that we gloss over some highly controversial topics in metaphysics and philosophy of science. Several important questions are given much less attention than they deserve.

Physics and Everything Else

Carroll is a scientific realist, at least at the level of physics. He believes that fundamental theories are either true or the best approximations to the truth currently available. That is not to say there is anything wrong with non-fundamental theories. He believes that thermodynamics is also true. It just describes the world as seen at another scale. [7] Thermodynamics provides a coarse-grained description of physical reality, carving nature into larger chunks than atomic theory. In fact, Carroll believes that chemistry, biology, and even psychology are true. I can rightly say that I scratch the back of my head *because* I want to stop an itch.

But how can that be? Is the difference between psychology and physics really just a matter of fine as opposed to coarse descriptions? After all, psychology and physics describe the world in completely different ways. Psychology makes no reference to atoms and is indifferent to whether they work according to classical or quantum mechanics. Even within the natural sciences themselves, physics makes heavy use of laws while biology has only a handful. In what sense are all these theories, with their own ontologies and methods, true? For Carroll, differences in terminology are merely the result of one reality being carved up in different ways. Unlike some reductionists, he denies that fundamental laws at lower levels *cause* upper-level phenomena. Causation itself is a derived concept, he says, not a fundamental one. [8] Instead, fine-grained and coarse-grained theories are just

[7] See Carroll, **The Big Picture…**, p. 373.

[8] See Carroll, **The Big Picture…**, p. 375.

different ways of describing events in physical reality:

> If you give me the precise and complete quantum state corresponding to "a person feeling an itch", and I have the calculational abilities of Laplace's Demon, [9] I could predict with extraordinary accuracy that the quantum state will evolve into a different state corresponding to "a person scratching themselves". No further information is needed, or allowed. [10]

The last clause is important. Physics *forbids* a description of mental causation that could even in principle fail to be captured by fundamental physics. Scientific truths at all the different scales must harmonize somehow or other. Which description one chooses is a matter of convenience.

Why think this is the case? Let's begin with a paradigm case of coarse-graining. [11] We can describe a system in terms of atomic physics and statistical mechanics on one hand, or by temperature, entropy, and thermodynamics on the other. Consider the gas in a sealed bottle. The overall state of the system is represented by the set of position and momentum values for each constituent atom taken at an instant. Given all the possible configurations and number of atoms, this is a vast amount of information. Nonetheless, each possible state can be represented by a single point in a sufficiently large mathematical space, the phase space. As the system changes over time, a trajectory is carved through the phase space as the representative state point evolves from one to another.

Thermodynamics is much less fine-grained. There will be far fewer possible states for the gas in the bottle in terms of thermodynamic properties such as temperature and pressure. The relationship between the two sets of descriptions is many-to-one. There are many micro-states all of which correspond to one macro-state. This makes sense. If you could change the direction of two atoms moving in the bottle, that would constitute a change of state at the lower level, but this micro-change would not register as a change of temperature or pressure. One of the

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[9] A Laplacian demon is a thought experiment in which a super-intelligence could calculate the future state of the universe based on the position and momentum of each particle at a given instant.

[10] Carroll, **The Big Picture…**, p. 374.

[11] Carroll's *The Biggest Ideas in the Universe, Vol. 21: Emergence* (2020, August 11, https://tiny.pl/9vkm9 [23.10.2021]) is helpful. While YouTube is not a scholarly source, it helps to see the relevant diagrams developed in a step-by-step fashion. Hossenfelder's case is basically the same as Laplace: Particle behavior is correctly described by differential equations. Differential equations are deterministic. You are made up of particles. Therefore, your behavior is deterministic.

great triumphs of classical physics is the ability to map the state spaces of the more fundamental theory, statistical mechanics, to the higher-level theory, thermodynamics.

So there is one system, the gas in the bottle, under two different descriptions that can be mapped from one to another. [12] But we can also say how the system will evolve from one state to the next. This can be done at the micro-level in terms of the mechanical interactions of the atoms, or at the macro-level in its appropriate vocabulary. While the laws used to track changes over time differ between the two theories, they preserve the mapping of states between the two scales. It is therefore merely a matter of convenience which theory one uses given that macro-changes correspond to micro-changes. In Carroll's view this is because the macro-theory *just is* a coarse-grained description of one and the same system.

While it is not as explicit as other accounts, Carroll's view is a type of reductionism. Macro/nonfundamental theories are useful, even "true" in some sense or other, but they are in principle not needed. A modified Laplacian demon could do all the micro calculations and then map the result to not only thermodynamics but to whichever macro description one might want. As the earlier quote makes clear, if the system in question is a human person, then the Laplacian demon could start at the even more fundamental level of quantum mechanics and correctly predict the behavior of that person. This includes, according to Hossenfelder, the outcome of an election. [13]

Why then is libertarian freedom forbidden? Because if the micro-physics evolves deterministically, which I have granted, it is not possible for higher-level descriptions to do otherwise. Pressure and temperature changes in the bottle can-

[12] This presumes that thermodynamics has been fully reduced to statistical mechanics. While this presumption is not outright false, it ignores a great many complications. For the mapping between the two scales to work, physicists must treat the bottle as having an infinite number of particles — the so-called "thermodynamic limit" — which is obviously not the case. There are several postulates like this that must be added to statistical mechanics for the derivations to work, but which lack a physical justification. In short, the "reduction" of thermodynamics to statistical mechanics is a continuing area of research in both physics and the philosophy of physics. See Lawrence Sklar, **Philosophy of Physics**, *Dimensions of Philosophy Series*, Westview Press, Boulder 1992, chap. 3 for more.

[13] See Sabine Hossenfelder, "The Case for Strong Emergence", in: Anthony Aguirre, Brendan Foster, and Zeeya Merali (eds.), **What Is Fundamental?,** *The Frontiers Collection*, Springer International Publishing, Cham 2019, p. 90 [85–94], https://doi.org/10.1007/978-3-030-11301-8_9.

not diverge in indeterministic ways given their unbreakable link to deterministic changes among atoms. The same principle applies to mental states. One's "choices" are constrained to evolve only in the ways that physics permits. After all, on this account the mental just is the physical at a different level of description.

There is a lot to criticize here, especially Carroll's rather optimistic view about how the micro and macro are related. In particular, not all levels — even within physics itself — "mesh" in the way he describes. [14] For our present purposes, let's ignore that and focus instead on two popular ways out of Carroll's reductionism that would allow for libertarian freedom. The question of interest will be whether these alternatives entail a violation of the laws of nature.

Possible Solutions

One solution appeals to mind–body dualism. Minds are not subject to the laws of nature. [15] If free will is a capacity of immaterial minds, then whatever physics has to say about the matter is largely irrelevant. [16] Dualism, of course, has its own problems. Perhaps the weightiest objection is that dualism entails the violation of a fundamental law: conservation of energy. [17] This is not the charge that the causal interaction between matter and mind is mysterious and unexplained. The claim is

[14] Which Carroll and other physicists certainly know, so his cherry-picking thermodynamics to make this point is somewhat surprising. Perhaps he thinks of it as an ideal that the non-meshing examples would conform to if we only knew enough. Jeremy Butterfield instead shows (i) the many ways in which meshing is limited or requires ineliminable idealizations, and (ii) that physics allows a failure to mesh such that micro-determinism induces macro-indeterminism. See Jeremy Butterfield, "Laws, Causation and Dynamics at Different Levels", *Interface Focus* 2012, Vol. 2, No. 1, sec. 3.2, pp. 101–114, https://doi.org/10.1098/rsfs.2011.0052.

[15] This presupposes that minds are immaterial and that all the laws of nature are at least potentially discoverable by the natural sciences. It is possible, however, that there are laws that we have no epistemic access to.

[16] This idea goes back at least as far as physician Georg Ernst Stahl in the early eighteenth century. See Thomas Ahnert, "Soul and Mind", in: Aaron Garrett (ed.), **The Routledge Companion to Eighteenth Century Philosophy**, *Routledge Philosophy Companions*, Routledge, London 2014, p. 311 [297–319]. It was also promoted by the prominent Swiss physicist Leonard Euler. See Wolfgang Breidert, "Leonhard Euler and Philosophy", in: Robert E. Bradley and Charles Edward Sandifer (eds.), **Leonhard Euler: Life, Work, and Legacy**, *Studies in the History and Philosophy of Mathematics*, Vol. 5, Elsevier, Amsterdam 2008, pp. 103–104 [97–108].

[17] See John R. Searle, **Mind: A Brief Introduction**, *Fundamentals of Philosophy Series*, Oxford University Press, New York 2004, p. 42.

instead that for a mind to influence a brain, energy must be exchanged. But if this material system gains energy from an immaterial one, then a human brain would constitute an illicit energy source within the physical world, a location where energy appears to be created from nothing. So while dualism might provide space for libertarian freedom by getting beyond the reach of the laws of dynamics — those that govern change from one state to another — it does so at the price of violating an equally fundamental law. This is what Daniel Dennett refers to as dualism's "inescapable and fatal flaw". [18]

But dualism is not the only option. Perhaps some form of emergence would work. Emergence is based on the idea that higher-level phenomena, like that studied in plant biology and neuroscience, are grounded in and yet fundamentally different from fundamental physics. Emergentists reject Carroll's claim that all higher-level theories are merely coarse-grained descriptions of those found in quantum mechanics. Emergent levels introduce something novel within nature. Not only has, say, biological life never been reduced to purely chemical properties, it cannot be, says the emergentist. Even an ideal, complete knowledge of chemistry would not allow one to predict what species will appear in an ecosystem.

Many emergentists argue that in human beings and some other animals, consciousness is an emergent capacity. [19] For those who also believe in free will, this often includes some form of downward causation: mental states must be able to influence brain states to thereby control one's body. Unlike dualism, this cause is naturalistic. The lower levels simply have a new causal influence in the mix. What *sort* of causal influence is highly controversial, but I do not want to engage that controversy here. Suffice to say that some believe the very idea of top-down cau-

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[18] Daniel Dennett, **Consciousness Explained**, Little, Brown and Co., Boston 1991, p. 35.

[19] This is usually called *strong/ontological emergence*: something new comes into being with its own causal capacities. All reductionists reject strong emergence, but many accept weak/epistemological emergence such that it is not currently possible to explain or predict higher-level phenomena from the standpoint of fundamental physics. For several varieties of both strong and weak emergence, see Timothy O'Connor, "Emergent Properties", in: Edward N. Zalta (ed.), **The Stanford Encyclopedia of Philosophy**, Fall 2020 (Metaphysics Research Lab, Stanford University, 2020), https://tiny.pl/9vkns [23.10.2021]. For a recent defense of weak emergence, see Jessica M. Wilson, **Metaphysical Emergence**, Oxford University Press, Oxford 2021. And there are intermediate positions, such as Bishop and Ellis's "contextual emergence". See Robert C. Bishop, **The Physics of Emergence**, IOP Concise Physics, San Rafael 2019; Robert C. Bishop and George F.R. Ellis, "Contextual Emergence of Physical Properties", *Foundations of Physics* 2020, Vol. 50, No. 5, pp. 481–510, https://doi.org/10.1007/s10701-020-00333-9.

sation is "in opposition to science" [20] and those who believe in downward causation understand it in different ways. [21]

While this is little more than an acknowledgment of emergence and downward causation, it will have to do for now. Let's just stipulate that robust accounts of consciousness as an emergent property exist, most of which allow for free will. [22] The discussion here will focus on a specific objection. Among the many criticisms leveled by old school, reductive physicalists, one stands out in my view: downward causation would violate the causal closure of physics. Under closure, physical events are sufficient to bring about other physical events. Higher-level "causes" would at best be redundant. The only real causes, they say, reside at the most fundamental level of physics. Mental causes cannot exist.

Very well, but why should we believe in the causal closure of physics? Why believe that the only causes reside at the most fundamental level, assuming there is one? Closure is certainly a key piece of reductionist dogma, but that is not itself an argument in its favor. David Papineau has famously tried to fill this void and make a case for causal closure. [23] Most of his arguments beg the question in my view, but one stands out: The causal closure of physics is entailed by the conservation of energy. If energy is conserved at the level of physics, then any causal influence from "above" would be adding to the total supply of energy at that level. Irreducible

[20] James Ladyman and Don Ross, **Every Thing Must Go: Metaphysics Naturalized**, Oxford University Press, Oxford 2007, p. 57 n. 54.

[21] See Michele Paolini Paoletti and Francesco Orilia (eds.), **Philosophical and Scientific Perspectives on Downward Causation**, *Routledge Studies in Contemporary Philosophy*, Vol. 91, Routledge, New York 2017; Jan Voosholz and Markus Gabriel (eds.), **Top-down Causation and Emergence**, *Synthese Library*, Vol. 439, Springer, Berlin 2021.

[22] As Jessica Wilson argues, emergentists can accommodate compatibilist free will without much difficulty. Libertarian free will is a harder lift. See Wilson, **Metaphysical Emergence…**, chap. 8. One anonymous referee suggests that an approach relying on causal powers might be helpful to the libertarian. It might, but I am somewhat skeptical of causal powers/dispositions/capacities. For those inclined otherwise, see William M.R. Simpson and Simon A.R. Horsley, "Toppling the Pyramids: Physics Without Physical State Monism", in: Christopher J. Austin, Anna Marmodoro, and Andrea Roselli (eds.), **Powers, Time and Free Will**, Springer International Publishing, Cham 2022, pp. 17–50, https://doi.org/10.1007/978-3-030-92486-7_2.

[23] See David Papineau, "The Causal Closure of the Physical and Naturalism", in: Brian P. McLaughlin, Ansgar Beckermann, and Sven Walter (eds.), **The Oxford Handbook of Philosophy of Mind**, Oxford University Press, New York 2009, pp. 53–65.

higher-level causes would thereby violate the conservation of energy — the same objection faced by mind–body dualism.

In short, all roads in this discussion lead to conservation. If libertarian freedom requires that conservation laws be violated, then it is set squarely in opposition not merely to reductive physicalism but to physics itself. One can see why Dennett calls this a fatal objection.

There is, however, one problem: conservation laws do not work the way naturalistic philosophers often assert. They claim that such laws are fundamental, absolute, and "indefeasible". [24] This is false. Unlike force laws or laws governing changes of state (e.g., Newton's second law of motion), conservation laws are conditional, and those conditions can fail to be met. What these conditions amount to has been rigorously explained in a recent series of papers by J. Brian Pitts and another coauthored with Alin Cucu. [25] For our purposes, most of the mathematics can be dispensed with if we focus on the conservation of energy and a famous proof by mathematician Emmy Noether. The upshot is that in cases where the necessary conditions are not met, conservation laws are not violated; they simply do not apply. As I will argue, insofar as libertarian freedom is a capacity grounded in interactive dualism or a sufficiently strong form of emergentism, it does not violate any conservation laws. First, let's consider why the conservation of energy is conditional rather than absolute. [26]

[24] Evan Fales, **Divine Intervention: Metaphysical and Epistemological Puzzles**, Taylor & Francis, New York 2010, p. 13.

[25] See J. Brian Pitts, "Conservation Laws and the Philosophy of Mind: Opening the Black Box, Finding a Mirror", *Philosophia* 2019, Vol. 48, pp. 673–707, https://doi.org/10.1007/s11406-019-00102-7; Alin Cucu and J. Brian Pitts, "How Dualists Should (Not) Respond to the Objection from Energy Conservation", *Mind and Matter* 2019, Vol. 17, No. 1, pp. 95–121; J. Brian Pitts, "General Relativity, Mental Causation, and Energy Conservation", *Erkenntnis* 2020, https://doi.org/10.1007/s10670-020-00284-7; J. Brian Pitts, "Conservation of Energy: Missing Features in Its Nature and Justification and Why They Matter", *Foundations of Science* 2021, Vol. 26, No. 3, pp. 559–584, https://doi.org/10.1007/s10699-020-09657-1.

[26] Cucu and Pitts consider the same three cases in their defense of dualism, but draw different conclusions in the first two. In the third case, based on Noether's theorem, we are in complete agreement. See Cucu and Pitts, "How Dualists Should (Not) Respond to the Objection from Energy Conservation…".

Conservation Laws

A. General relativity

The first of three reasons may come as a surprise: according to general relativity, energy is not typically conserved. On some accounts, this is due to the total amount of energy changing over time in an expanding universe. Hossenfelder puts it succinctly: "I said that energy is conserved, but that is only approximately correct. It would be entirely correct for a universe in which space does not change with time. But we know that in our universe space expands, and this expansion results in a violation of energy conservation". [27] Carroll shows how the total energy [28] contribution of matter, radiation, and vacuum energy in an expanding universe "is clearly not conserved. […] This is upsetting, since conservation of energy is one of the more cherished principles of physics". [29]

The more technical way of drawing this conclusion relies on Killing vectors. The rough idea is that if one takes a set of points in space and then moves them in a way specified by a Killing vector, those points will maintain their relative distance. [30] There will be no expansion or contraction of the distance between those points. As Maudlin *et al.* show, energy can be defined when space-time contains a field of Killing vectors. Special relativity has an infinite number of them. The situation is different, however, in general relativity:

> There, in the generic case and certainly for the actual universe, instead of an infinitude of global time-like Killing fields, there are none. There is therefore no reason — if this is the correct account of the nature of "energy" — to expect any principle of exact global conservation of energy to obtain. The conclusion is admittedly somewhat disconcerting, but there it is. [31]

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[27] Sabine Hossenfelder, "10 Physics Facts You Should Have Learned in School but Probably Didn't", *BackReAction* 2018, July 30, https://tiny.pl/9vkb7 [23.10.2021].

[28] More precisely, the energy density over which an integral can be taken.

[29] Sean Carroll, **Spacetime and Geometry: An Introduction to General Relativity**, Cambridge University Press, New York 2019, p. 120.

[30] See Benjamin Crowell, **General Relativity**, Fullerton College, Fullerton 2022, sec. 7.1, https://tiny.pl/9vkbs [23.10.2021].

[31] Tim Maudlin, Elias Okon, and Daniel Sudarsky, "On the Status of Conservation Laws in Physics: Implications for Semiclassical Gravity", *Studies in History and Philosophy of Science Part B: Studies in*

Experts will point out that there are ways of defining energy-surrogates in order to reestablish a kind of conservation, especially in small regions of spacetime. [32] Nonetheless, it is commonly argued that conservation of energy does not hold in curved spacetimes. [33]

For our purposes, the key point is this: conservation of energy is not absolute. There are conditions for it to hold and those conditions can fail. And when they fail, physics does not come crashing down. Curved spacetimes in general relativity do not *violate* energy conservation. Rather, the law does not apply.

B. Closed systems

A more familiar approach to the question of conservation has to do with open and closed systems. Undergraduate textbooks teach that both conservation of energy and conservation of momentum only apply in a closed or isolated system. [34] An open system is either influenced by outside forces or it allows particles to enter or leave. In such a system, conservation does not obtain. Again, the laws are not violated. The laws are conditional, and the conditions are not met in an open system.

That seems clear enough. Why doesn't the case for conservation being conditional end here? The answer is that this is not the way that physicists deal with conservation in practice. It is a pedagogically useful step that coincides with a more rigorous formulation most of the time, but there is a better approach, which we will get to next.

History and Philosophy of Modern Physics 2020, Vol. 69, p. 70 [67–81], https://doi.org/10.1016/j.shpsb.2019.10.004.

[32] See Robert M. WALD, **General Relativity**, University of Chicago Press, Chicago 1984, pp. 69–70.

[33] See Sean CARROLL, "Energy Is Not Conserved", *Preposterous Universe* 2010, February 22, https://tiny.pl/9vk3b [23.10.2021]. Pitts is one of the contrary voices on this point, arguing that conservation does in fact hold in general relativity. See his "General Relativity, Mental Causation, and Energy Conservation…", sec. 6.

[34] In thermodynamics, "closed" means that particles cannot cross the boundary of a system. "Isolated" is stronger: neither mass nor energy can cross the boundary. A snow globe is closed, hence you don't get the fake snow all over you, but the fact that you can shake it shows that the system is not isolated. See Jerry B. MARION and Stephen T. THORNTON, **Classical Dynamics of Particles & Systems**, 3rd ed., Harcourt Brace Jovanovich, San Diego 1988, p. 217.

Another problem is that when physicists talk about an open system, they have in mind something that is part of a larger *physical* system. To say that a system is open means that it is not cut off from its environment. [35] It would not be appropriate for a dualist to describe the brain as an open system insofar as it interacts with an immaterial mind. The brain, like any physical system, only counts as "open" when it interacts with its environment, not when it interacts with something nonphysical. The open/closed distinction therefore does not apply to nonphysical causal influences, if there are any. Let's now consider a better approach.

C. Noether's theorem and symmetry

Philosophers often take "classical physics" to be roughly synonymous with "Newtonian mechanics", but that is not quite right. [36] Newtonian forces often become unmanageable, even for relatively simple systems like a bead sliding down a wire. Thankfully, physicists found ways to describe such systems so that energy becomes the central feature, rather than force. One of these approaches is Lagrangian mechanics. Whether and when the conservation of energy holds is most obvious here. [37] A Lagrangian L is a mathematical function describing the energy of a system. Let's take a simple case: a weight on the end of an ideal spring that oscillates along one dimension. [38] To say that it is an ideal spring means that we are ignoring both friction and gravity. The kinetic energy of the spring is $\frac{1}{2}mv^2$ and the potential energy is $\frac{1}{2}kx^2$. (The variables in the first expression are for mass and velocity. The constant k in the second one depends on the stiffness of the spring and x is the distance that the weight travels.) L is the kinetic minus the potential energy. Plugging L into the (Euler–Lagrange) equations of motion provides a model of the behavior of the system — a differential equation for the behavior of

[35] See Hans Halvorson, "Plantinga on Providence and Physics", *European Journal for Philosophy of Religion* 2013, Vol. 5, No. 3, p. 25 [19–30], https://doi.org/10.24204/ejpr.v5i3.216.

[36] See Mark Wilson, "Mechanics, Classical", in: **Routledge Encyclopedia of Philosophy,** 1st ed., Routledge, London 2016, https://doi.org/10.4324/9780415249126-Q068-1.

[37] See Pitts, "Conservation Laws and the Philosophy of Mind…", pp. 683–684.

[38] See Marion and Thornton, **Classical Dynamics of Particles & Systems…**, p. 193. The same example and general line of argument was previously used in: Jeffrey Koperski, **Divine Action, Determinism, and the Laws of Nature**, Routledge, New York 2020, pp. 139–142, https://doi.org/10.4324/9780429029110.

that type of spring. This is a particularly simple, idealized system, but nothing in this analysis hangs on that.

A key concept in modern physics is the notion of *symmetry*. A perfect sphere exhibits a type of geometric symmetry in that it looks the same from any angle. Its appearance is, in other words, invariant with respect to the angle of observation. We would also say that the speed of a car is invariant unless it is accelerating or braking. When a system has a symmetry, something or other is invariant. Consider watching two people playing ping-pong in a large shipping container. The paddles, ball, and table all behave the same, familiar ways no matter whether the container is in Poznań or Detroit. In fact, wherever on the Earth it is, the dynamics of the game are unaffected. They are invariant with respect to where on the planet the container rests. Likewise when it comes to when the game is played. Whether it starts now or a decade in the future, the ball bounces in the same way. Game-mechanics are invariant with respect to time.

According to Noether's theorem, each conserved quantity — energy, charge, etc. — depends on a symmetry. The two previous examples illustrate the symmetries we are interested in. Conservation of momentum is a consequence of the spatial translation invariance of a Lagrangian. This means that no matter where in space you move (translate) the system, its Lagrangian remains the same (invariant). This holds for the ideal spring. No matter where in space we put it, L remains the same. Conservation of energy is entailed by time translation invariance: no matter when in time such a system exists, its Lagrangian is unchanged. For the ideal spring, the date that it is operating makes no difference to L and so energy is conserved. Intuitively, time translation invariance means that however a system behaves, it will act the same way whenever the system exists. Mathematically, the Lagrangian in this case is not a function of time and therefore cannot change over time. The *state* of the system does, of course, change over time. By design, the spring will oscillate back and forth. While the ideal spring can oscillate indefinitely, the relation between potential energy and kinetic energy described by L remains the same.

The test for whether conservation of energy applies to a given system comes down to this: does the expression for its Lagrangian explicitly depend on time? More formally, is L a function of time? If it is not and the Lagrangian is independent of time, then energy is conserved. If on the other hand the Lagrangian changes over time, then one cannot infer conservation. (An analogous situation holds in quantum mechanical systems.[39] Nothing important here hinges on whether we are talking about a classical or quantum system.)

For a simple harmonic oscillator like the ideal spring, $L=\frac{1}{2}mv^2-\frac{1}{2}kx^2$. Since m and k are constants, L is only a function of v and x. The fact that L is time-independent is captured by its derivative with respect to time: $\partial L/\partial t=0$. If L depended on time the way it does velocity or position, then the derivative would not be zero.

Now consider a case where energy is not conserved. Take the same ideal spring, but stipulate that the mass is magnetic. Now place an electromagnet near the apparatus, one in which the signal varies sinusoidally over time. L no longer applies to this system. Instead, an additional term will be needed to account for the influence of the electromagnet. And since that influence changes over time, the new Lagrangian, L^*, must include a time variable t. Unlike the previous case, L^* is a function of time and so $\partial L^*/\partial t\neq 0$, thus failing the test for time translation invariance. By Noether's theorem, conservation of energy does not apply. The same test works whether the system is composed of rigid bodies, particles, or fields. If the expression for the Lagrangian explicitly depends on time, conservation of energy does not hold. This example shows why the open/closed terminology often gets it right. The magnetic spring is not isolated from the influence of the electromagnet and therefore constitutes and open system in which conservation fails.

But wait, is it really that easy to negate conservation? "I was assured that conservation of energy is fundamental, absolute, and indefeasible!" — the skeptical reader objects. In fact, engineers and applied physicists routinely deal with systems in which conservation does not hold. Conservation is desirable because it makes solving the relevant equations easier. When applicable, it provides a *constant of motion*.[40] If enough constants of motion can be found, then a set of differential equations can be solved using straightforward calculus. Unfortunately, most real-world systems are not like that, although they are often close enough that engineers can treat them as such.

Let's consider an objection. In the second spring example, what counts as "the

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[39] See Robert L. Jaffe and Washington Taylor, **The Physics of Energy**, Cambridge University Press, Cambridge — New York 2018, p. 405.

[40] See Michael Tabor, **Chaos and Integrability in Nonlinear Dynamics: An Introduction**, Wiley, New York 1989, pp. 2–5.

system" is somewhat arbitrary. Nothing prevents us from including the electromagnet, the source of the external perturbation. Instead of an outside influence on the spring, the electromagnet becomes part of the system itself. Doing so transforms the open system into a closed one. In this case, a new time-translation invariant Lagrangian will replace L^*, thereby restoring conservation. In fact, conservation can always be restored, we are told, if only we redraw the boundaries in appropriate ways, recapture all the heat lost to friction, or perform some analogous procedure for other types of dissipation. [41] It is in this sense that many believe conservation of energy is universal and absolute.

So then, is this the case? Can conservation of energy always be restored, at least in principle, merely by reconfiguring the boundaries? This brings us to the most controversial part of the discussion. For reductionists, it simply has to be possible. If conservation holds at the most fundamental level of physics, say within the Standard Model, then it holds absolutely since everything is made up of fundamental particles. Boundaries can always be appropriately redrawn in principle, ensuring that conservation of energy does not fail. Physics thereby shows that it is a fundamental law.

In reply, we should first note that this is an expression of faith, which the qualifier "in principle" usually is. There is no theorem, theory, or observation that entails such a conclusion. And there are counterexamples. Big Bang cosmology is one, as we have seen. Conservation of energy would likewise fail for other cosmological models, such as Bondi and Gold's steady-state model. [42] If the GRW (Ghirardi–Rimini–Weber) interpretation of quantum mechanics is correct, then conservation does not always hold. [43] And types of conservation other than energy have been shown to have exceptions in nuclear physics. The redrawing-of-boundaries strategy cannot fix these cases. As Butterfield concludes, the "principle of the

[41] See Evan Fales, "It Is Not Reasonable to Believe in Miracles", in: J.P. Moreland, Chad Meister, and Khaldoun A. Sweis (eds.), **Debating Christian Theism**, Oxford University Press, New York 2013, p. 300 [298–310].

[42] See E.J. Lowe, **Personal Agency: The Metaphysics of Mind and Action**, Oxford University Press, Oxford 2010, p. 41.

[43] The spontaneous collapse of a quantum wave packet that is described in the GRW interpretation does not conserve momentum or energy. See Shan Gao, **The Meaning of the Wave Function: In Search of the Ontology of Quantum Mechanics**, Cambridge University Press, Cambridge 2017, p. 145.

conservation of energy is not sacrosanct”. [44]

Moreover, there is no way to redraw boundaries to include all gravitational effects. Gravity influences every material system and has no range limit. The only boundary that encompasses the gravitational influence of every particle of matter would extend to the entire observable universe. This, however, makes the system in question the expanding universe itself, which leads back to the problem of conservation in cosmology.

One reason for treating conservation of energy as absolute is that it is pedagogically useful to do so. Counterexamples and exceptions are the sorts of things best left for graduate studies. Nonetheless, at least one popular textbook treats the subject with the subtly it deserves:

> It must be reiterated that we have not proved the conservation laws of linear momentum, angular momentum, and energy. We have only derived various consequences of Newton’s laws; that is, *if* these laws are valid in a certain situation, then momentum and energy will be conserved. But we have become so enamored with these conservation theorems that we have elevated them to the status of laws and we have come to *insist* that they be valid in any physical theory, even those that apply to situations in which Newtonian mechanics is not valid, as, for example, in the interaction of moving charges or in quantum-mechanical systems. We do not actually have conservation laws in such situations, but rather conservation *postulates* that we force on the theory. [45]

That last sentence might be rather surprising, but there are many such principles used in physics. So far as we can tell, for example, nature is uniform: the laws that apply locally work that same way everywhere else. This has been a useful postulate, one that astrophysics relies on, but has recently come into question. [46] Like mature theories, scientists tend to use such metatheoretic shaping principles until anomalies and exceptions force a change. Determinism continues to be a useful postulate in many areas of physics, even though quantum mechanics has fa-

[44] Jeremy Butterfield, “Quantum Curiosities of Psychophysics”, in: John Cornwell (ed.), **Consciousness and Human Identity**, Oxford University Press, New York 1998, pp. 146–147 [122–159].

[45] Marion and Thornton, **Classical Dynamics of Particles & Systems…**, p. 74. The view expressed here is based on the physics presented in this section of the paper. The quote is exceptional only insofar as most undergraduate texts do not take time to explain the subtleties involved.

[46] See Mordehai Milgrom, “MOND *vs.* Dark Matter in Light of Historical Parallels”, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 2020, Vol. 71, No. 4, pp. 170–195, https://doi.org/10.1016/j.shpsb.2020.02.004.

mously introduced cases where it fails. This, following Marion and Thornton, is the best way to think about conservation laws. They are useful postulates that are assumed to work unless a defeater is present. They are not bedrock, unexceptional truths that science must conform to come what may.

We should finally note that most laws of physics are not conditional in the manner described in this section. Conservation laws are different from dynamical laws (like Newton's second law of motion) and force laws (like Coulomb's law of electrostatics). The latter are not dependent on symmetries the way that Noether proved conservation laws to be.

Conclusions

We have considered two ways that a libertarian might escape the objection that free decisions violate the laws of nature, one appealing to dualism and the other to emergence with top-down causation. Let's make some applications. First, what should the dualist say? As Cucu and Pitts rightly argue, what might have seemed implausible appears to be exactly the right approach: If a mind acts on a body, then energy is not conserved. [47] The influence of a mind on a body is not constant over time, so time translation invariance does not apply to a mind–body system. (Roughly, the mind influences the body to different degrees at different times.) And if this invariance fails, then according to Noether's theorem, energy is not conserved for that system at that time. Note that, despite the cries of some reductionists, physics would not come crashing down if this were the case. Local exceptions to conservation are nomically permissible. Mind–body interactions do not affect collision experiments in a lab, for example.

What about emergence? If downward causation is taken at face value, then there are causal contributions from higher levels that impinge on lower ones. And if mental activity (strongly) emerges from the level of neurophysiology, then events such as the exercise of will start a causal chain that ends with changes to fundamental particles (e.g., the protons in my hand move toward those in a coffee mug). Presumably such mental events are episodic and so this causal influence

[47] See Cucu and Pitts, "How Dualists Should (Not) Respond to the Objection from Energy Conservation…", sec. 6. Alvin Plantinga also briefly makes this point in: Alvin Plantinga, "Materialism and Christian Belief", in: Peter Van Inwagen and Dean W. Zimmerman (eds.), **Persons Human and Divine**, Oxford University Press, New York 2007, pp. 126–127 [99–141].

changes over time, just like in dualism, and so time translation invariance fails in this case as well. Conservation of energy therefore does not apply.

Perhaps there are ways of grounding libertarian freedom without either dualism or downward causation, but these two, at least, do not violate the conservation of energy as is commonly supposed. Thankfully, Noether's theorem tells us precisely when conservation applies and when it does not. Given the lack of time translation invariance in both cases, conservation of energy does not apply and therefore cannot be "violated".

The aim of this paper was to rebut objections to libertarian freedom based on conservation of energy. That much, I believe, has been accomplished. But it is not yet clear whether physics is amenable to libertarianism. There is more work to be done on the questions of causal closure, determinism, emergence, and more. Unlike many that's-work-for-another-time promissory notes, I do intend to address these issues in the future. [48]

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