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Book Review

Lee Smolin
Einstein's Unfinished Revolution
Lee Smolin, *Einstein's Unfinished Revolution,* Penguin Press, 2019, 16.99 USD, ISBN 9781594206191

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Overview

In keeping with the spirit of the book review section of IJQF, which encourages sweeping reviews that are opinionated dialogue starters, this review will go well beyond the usual boiler plate synopsis plus quality rating. However, I'm a firm believer that a book review should not merely be a stalking horse for the reviewer's own opinions and value judgements. This review will certainly not be merely that kind of exercise. However, I'm not above using a book review to engage in a little professing as it were. After all, this is where dialogue begins. I'm also going to bring in some other recent works of Smolin that help illuminate and fill in gaps in *Einstein's Unfinished Revolution,* though of course the focus here is on the latter.

Smolin says his primary audience is a lay group of those with a deep and abiding curiosity about the foundations of physics, but probably with little formal or mathematical training. This is a book meant for a popular audience. Smolin has indeed hit his mark. The book is beautifully written and engaging, as his books tend to be. I would also say that practitioners of foundations or theoretical physics will, as I did, benefit greatly from reading this book. The primary focus of the book is on quantum mechanics (QM). However, Smolin makes it clear that he wants an account of QM that comports deeply with the spacetime of relativity. He believes trying to understand or interpret QM in isolation from the project of unification and quantum gravity is a mistake, and he seeks nothing less than to discover the nature of matter itself. Thus, the book certainly goes "beyond the quantum." I am in general sympathy with most of these claims.

The book is divided into three sections. The first section ("An Orthodoxy of the Unreal") sets up the entire book by giving an overview of quantum weirdness such as superposition and entanglement, but primarily focuses on the tendency towards anti-realist accounts of QM at its origins and the current trend back toward anti-realist accounts. His targets of course include, Bohr, Heisenberg, quantum Bayesianism (QBism), and pragmatic accounts such as Healey (2020). As he puts it, "But when fundamental physics itself gets hijacked by an anti-realist philosophy, we are in danger. We risk giving up the centuries-old project of realism" (2019, p. xxv). Smolin is clear that for him the holy grail of physics is to reveal the fundamental nature of reality. Indeed, this is the main meaning of the title of the book. Einstein's unfinished revolution is a realistic account of QM that meets all the goals enumerated in the preceding paragraph.

I am again in sympathy with Smolin that the primary goal of physics is, or ought to be, to help reveal the nature of reality. I also agree that the current anti-realist trend is largely defeatist, an unhelpful retreat in the face of underdetermination and the like. If one thinks Smolin's concern

is alarmist, I would suggest reading the edited volume *Scientific Realism and the Quantum* (2020), wherein many argue for some version of the claim that, "the appropriate attitude towards quantum mechanics is one of anti-realism: agnosticism about its ontology, coupled with instrumentalism about its theories" (French and Saassi, p. 3, 2020). Whether one is a practicing physicist or philosopher of physics, I believe we are all better off creating, working on, shaping or critiquing particular models, rather than focusing on stock second-order philosophical concerns such as the perennial realism/anti-realism debate in philosophy of science. This is one reason why I admire Smolin, irrespective of whether I agree with the particular direction in question, he is continually engaged in model building. I will however return to a more nuanced discussion of scientific realism, as there are many different versions in play, and they must be analyzed separately. Or to put it another way, one must be careful not to paint all "anti-realist" claims and projects with the same brush.

The second section ("Realism Reborn") focuses on realist accounts of QM both past and present, such as de Broglie Bohm, Bohmian mechanics, collapse accounts, etc. Smolin applauds such realist attempts but details why he thinks they are all lacking. In short, Smolin is betting that quantum mechanics and its current variants are false or incomplete. Throughout the first two sections of the book one gets an excellent lay introduction to many name brand interpretations or alternatives to quantum mechanics, as well as their widely advertised flaws.

In the third section ("Beyond the Quantum") Smolin provides a sketch of his own account of quantum gravity and unification, and how such an account might resolve the outstanding mysteries of quantum mechanics such as the measurement problem, superposition, entanglement, non-locality, etc. Ironically, Smolin argues that a fully developed realist, constructive/constitutive account (roughly in Einstein's sense of those terms. See 1919, 1936 and 1949) is premature, thus we must begin with a principle account (again roughly in Einstein's sense of the word) and work backwards to a constructive one (p. 227, 2020). Smolin lays out his principle constraints on any such account and gives some other axiomatic "hypotheses" as well. With the foregoing as background, he begins to describe what he thinks the full constructive account might look like. More on his positive account shortly.

Going forward I'll unpack the key themes and claims throughout the book with an emphasis on what I think are certain internal tensions and other concerns in Smolin's account, provide a diagnosis as to how they got there and suggest an alternative that nonetheless is in the spirit of most everything Smolin wants and holds dear. In particular, I don't think Smolin's own account comports well with his own brand of "naïve realism" and that includes the way he claims to explain time as experienced, the emergence of space and the place of matter in his fundamental theory. That is, I don't think Smolin can have both his naïve realism and his brand of QG/unification. I'll argue that while Smolin is often portrayed as a radical iconoclast and his ideas outside the mainstream, his assumptions about what the project of quantum gravity (QG) is and ought to be, what such a theory should look like, are in fact the norm. Furthermore, some of those assumptions are possibly precisely where Smolin's account and other related accounts go astray. That is, just as the last few decades of effort attest, I don't think the pregeometric project of QG as standardly conceived and executed, has much chance of truly recovering or saving the phenomena, i.e., time, space and matter as experienced, because, to paraphrase Smolin, they are based on "incorrect foundations."

Internal Tensions: Realism

As indicated above, the first place one finds some internal tension is in Smolin's view that a realistic theory must ultimately be constructive/constitutive but that we are in no position to construct such a theory. As he puts it, "So, my conclusion is that we need to back off from our models, postpone conjectures about constituents, and begin again by talking about principles" (p. 227, 2019). One thing that makes this move especially ironic is that some of the projects that Smolin dubs anti-realist, such as quantum information theory (QIT), are also motivated by the apparent lack of progress in attempting to interpret or reframe quantum mechanics constructively (i.e., realistically). A lack of progress that Smolin chronicles in this book. For example, many physicists in QIT are calling for "clear physical principles" (Fuchs and Stacey, 2016) to account for QM. As (Hardy, p.43, 2016) points out, "The standard axioms of [quantum theory] are rather ad hoc. Where does this structure come from?" Fuchs points to the postulates of special relativity (SR) as an example of what QIT seeks for QM (Fuchs and Stacey, 2016), and SR is the exemplar of a principle theory (Felline, 2011). That is, the postulates of SR are principle constraints without a corresponding constructive explanation.

The reasons for seeking a principle explanation of QM include not just the ad hoc nature of the postulates, but the "fact that there is no agreement on constructive interpretations" (Van Camp, p. 2, 2011), in part because they do nothing but recover what is already in textbook QM, and therefore lead to no new physics or unification. For those who believe the fundamental explanation for QM phenomena must be constructive, at least in the sense presumably envisioned by Einstein, none of the mainstream interpretations neatly fits the bill. Not only do most interpretations entail some form of QM holism, contextuality, and/or non-locality, the remainder invoke priority monism and/or multiple branches or outcomes. The problem with attempting a constructive account of QM is, as articulated by Van Camp, "Constructive interpretations are attempted, but they are not unequivocally constructive in any traditional sense" (Van Camp, p. 21, 2011). I'll return to this theme later when I evaluate Smolin's positive account. The point is that while QIT in general and QBism in particular are exemplars of anti-realism in Smolin's book, Smolin shares their criticism of constructive or realist models of QM and he shares their search for a principle account of QM. So broadly speaking, what separates Smolin's project from the QIT project, at least with respect to the question of realism?

QIT continues to seek "the reconstruction of quantum theory" via a principle approach (Chiribella and Spekkens, 2016). Indeed, QIT has produced several different sets of axioms, postulates, and "physical requirements" in terms of quantum information, which all allege to "reproduce" quantum theory. Despite all the success of QIT, the community does not find any of the reconstructions compelling. As Hardy states, "When I started on this, what I wanted to see was two or so obvious, compelling axioms that would give you quantum theory and which no one would argue with" (as quoted in Ball, p. 227, 2017). Fuchs quotes Wheeler, "If one really understood the central point and its necessity in the construction of the world, one ought to state it in one clear, simple sentence" (Fuchs and Stacey, p. 302, 2016). Asked if he had such a sentence, Fuchs responded, "No, that's my big failure at this point" (Fuchs and Stacey, p. 302, 2016).

Perhaps then Smolin would simply say that he applauds the attempt of the QIT community's search for a principle theory but agrees with them that they have failed to find it. It goes deeper than that however, as Smolin is clear that Wheeler's "It from bit" as well as any of its modern day variants of "informationalism", "quantum Bayesianism" and the idea that the universe is literally a QM automata are all unacceptably "radical" instances of "anti-realism" (pp. xxvi-xxvi, pp. 188-89, p. 192, and p. 193, 2019). Why does Smolin think that such information-

based foundations for physics are inherently radical and anti-realist? To answer that question, we have to elucidate his conception of realism. Having done so, we can eventually return to the question of whether or not his own account of QG passes his own acid test for realism. What follows are the myriad claims that Smolin packs into scientific realism throughout the book:

1) The natural world exists independently from our minds and theories and has objective properties independent of our perception and knowledge, i.e., human measurement procedures and observers/observation cannot be in any way special. The idea is that were the universe to remain exactly the same minus conscious observers, this would change nothing about the physics of our world. Furthermore, Smolin is clear that any account of QM wherein measurements/interactions create properties or entities not inherent in the object (e.g., "Bohrians"), any account which holds that QM is about states of knowledge (e.g., "QM epistemologists"), any account that claims QM is only about what happens when we interrogate reality (e.g., "operationalists"), and any account that relativizes outcomes and definite values to observers who could disagree about the "same" QM system without contradiction (e.g., "perspectivalists"), fails to be realistic in full.

2) A realist account of QM must provide an ontology of "beables", not merely observables. Those beables must be empirically accessible in-principle-in-practice. "Naïve realism" which he defends, further holds that nature consists of the kinds of objects we see when we look around and the things that constitute them—what we experience is typical of the universe as a whole. Thus, one should be skeptical of any explanations of QM weirdness adverting to exotic theoretical posits that are in principle unobservable, such as many worlds in the Oxford-Everettian interpretation, varieties of the multiverse, Platonic information, etc. The idea here is that the universe is made of matter, we just have to figure out what that is. Furthermore, no account of fundamental physics should invalidate or render false everyday experience but should rather explain it. In other words, Smolin wants no part of a fundamental theory that implies eliminativism or illusionism about time, conscious experience or matter.

3) A realist account of QM should be about individual events or physical processes such as Bohmian mechanics or other accounts with singular causation. He wants an account of QM that explains what is happening in every specific token experiment and QM interaction. Relatedly, probabilities should be about ensembles of particles that really exist. In other words, to put it in the idiom of the laboratory, he wants an account of QM that tells us exactly what is happening in spacetime between source and detectors, just as it happens in the wild.

4) A realistic account of QM should apply to the universe as a whole, not just subsets, e.g., we should not have to posit things outside the theory such as observers or measurement makers to collapse or decohere the wavefunction of the universe.

5) A realistic account of QM assumes that humans can eventually comprehend all of the natural world. That is, any kind of explicit or assumed skepticism about our ability to eventually reveal, predict and manipulate fundamental physics is a non-starter.

It's clear that Smolin is defending a relatively sweeping and old-fashioned notion of scientific realism. One could defend much less ambitious and much more restrictive notions of realism for QM, as for example, many do in the volume *Scientific Realism and the Quantum* edited by French and Saassi (2020). It's also clear that many of tenants 1-5 are orthogonal, such that one could accept some and reject others. It's also possible that 1-5 might embody brands of realism that are in logical tension. To see this point more generally, take the following distinct versions of realism:

A. Realist theories must place bets about beables (i.e., about what there is independently of our perceptions, interventions, measurements, and theorizing).

B. Realist theories must posit beables *with certain particular features* as enumerated above, e.g., nothing too exotic by the lights of everyday experience, they must be non-contextual in nature, empirically accessible in-principle-in-practice, etc. This is Smolin's "naïve realism" as opposed to what he calls "magical realism", e.g., the Many Worlds interpretation of QM.

C. Realist theories assume our full epistemic access to all of the natural world in principle.

The tension alluded to here is an ancient one. How can one assert both that the deepest or most fundamental nature of reality, e.g., the noumenal world, could well be radically different than our perceptions, experiences and scientific theories suggest and also demand that fundamental reality must conform to our intuitions of space, time, matter, causation, etc? After all, this is the kind of concern that drove Kant's transcendental idealism.

And if we acknowledge that fundamental, mind-independent reality could be radically counter-intuitive, why should one assume our full epistemic access to all of the natural world in principle? As Callender puts it, "Most of what we say about the quantum realm is 'interpretation' dependent. The research programs described here portray radically different worlds from top to bottom, agreeing on little more than what is observable … In sum, we have serious scientific underdetermination" (pp. 72-75, 2020). Of course, Callender's point about "interpretation dependence" also applies to classical mechanics (point particles anyone?) and the everyday world (the Matrix anyone?), but it does seem especially odious in QM, where we most want to rely on our best science over everyday experience and intuitions. When we get to Smolin's own account, the question we'll want to ask is, does it fair any better as an exemplar of "naïve" or commonsense realism?

Underdetermination aside, what should we do when QM strongly suggests something about the nature of fundamental reality that violates our naïve, everyday conception of reality? Take the contextuality implied by the Kochen-Specker (KS) theorem and other more recent theorems. Contextuality goes against Smolin's tenant number 1 above. That is, given certain other assumptions that Smolin shares, KS implies that the following is false: If a QM system possesses a property (value of an observable), then it does so independently of any measurement context, i.e. independently of *how* that value is eventually measured. Recall that

Smolin thinks QM is false or incomplete and thus, like Einstein, he seeks hidden variables to complete it. The whole point of hidden variables is to get around KS (contextuality) and/or Bell's theorem (non-locality). And yet, this is what Smolin says, "The conclusion is that nature is contextual. This is the case with quantum mechanics, and experiments have been done which confirm this prediction of the theory. So, it must be true in any deeper theory which will replace quantum mechanics" (p. 56, 2019). He calls this result the "Bell-Kochen-Specker theorem" (p. 56, 2019). And as we will see, his own account has beables that are radically contextual, he calls them "relational hidden variables." Indeed, his hidden variables are also non-local. This seems like a violation of Smolin's own brand of realism and one wonders what is the point of hidden variables at all if they are contextual and non-local, i.e., if they don't skirt KS or Bell? And one wonders, how contextual can a "hidden variable" be and still be hidden, and still keep with Smolin's brand of realism? Without getting into a lot of historical exegesis, it's hard to believe Einstein would approve.

Smolin's Fundamental Theory

Let us then move on to Smolin's positive account. As he says, his goal is to "combine quantum physics and spacetime at the level of fundamental principles" (p. 229, 2019). The principles in question are as follows:

1. *Background independence*. Just as GR makes spacetime (geometry) dynamical, there should be no non-dynamical fixed, frozen, timeless features of any sort and presumably that includes laws; hence Smolin's well-known claim that laws evolve over time (Smolin, 2013). Such a theory will be a cosmological theory by definition and there can be nothing outside of the theory's scope (pp. 229-231, 2019). Smolin thinks this implies that all "observables of physical theories should describe relationships" (p. 231, 2019). That is, not just space and some aspects of time, but matter itself will be fully relational and dynamical. This suggests to Smolin that we should therefore seek not to quantize gravity, but to "gravitize the quantum" (p. 231, 2019).
2. Thus, space, matter, and some aspects of time (i.e., all the fundamental beables) are *fully relational* (p. 232, 2019).
3. *Causal completeness*. This is the claim that the chain of causes never exits the universe and that the fundamental physical theory is causally closed (p. 232, 2019).
4. *Principle of Reciprocity*: If A acts on B then B acts on A (p. 232, 2019).
5. *Principle of the identity of indiscernables*—PII, and all it entails (p. 233, 2019).

Again, these are merely necessary conditions for the ultimate theory and collectively these are all aspects of Leibniz's principle of sufficient reason (PSR) according to Smolin (p. 233, 2019).

Smolin then introduces us to three "hypotheses" to further constrain the space of acceptable theories (p. 236):

1) Time in the sense of (efficient) causation is fundamental.
2) Time is irreversible or asymmetric.
3) Space is emergent. Space (the continuum) arises as a course-grained and approximate description of the network of events and their causal interrelations. This implies that both locality and non-locality are emergent. The latter will be remnants explained as "defects" which occur in "the emergence of space from the spaceless relations inherent in the primordial stage, before space emerges"

> (p. 236, 2019). Smolin sometimes calls this idea "disordered locality." Specifically, space emerges from entangled states between discretized events (p. 238, 2019).

Smolin tells us that, "The combination of a fundamental time and an emergent space implies that there may be a fundamental simultaneity", what he calls a global preferred reference frame (p. 237, 2019). In Smolin (2013) he notes that there is a tension between PSR and the relativity of simultaneity in SR when we consider QM entangled correlations at space-like separation. His global preferred reference frame is supposed to reconcile this tension by ensuring that claims about causal relations are never merely frame dependent.

Hypotheses 1 and 2 are developed at length in Smolin (2013), but the idea is that time as change, i.e., "the irreversible flow of present moments" is fundamental (p. 237, 2019). Smolin is motivated to realistically explain the basic phenomenology of temporal experience, which he thinks the eternalism or block universe associated with relativity makes impossible. The phenomenological features in question are as follows:

- Passage or Flow: the world is in constant flux such that the future becomes the present and the present becomes the past.
- Presence: the present moment is experienced as special or ontologically privileged.
- Direction: time appears to flow irreversibly from a distinguishable past to a distinguishable future.

How does Smolin explain these essential aspects of temporal experience? He simply makes them axiomatic features of his fundamental physical theory. Or at least he thinks there are features in his fundamental theory that explain or correspond to Passage, Presence and Direction. Let us now unpack what this looks like.

What comes next then is what Smolin would describe as a sketch of his constructive theory. It is not easy to understand at first glance and I cannot possibly do it justice without a great deal of formalism, but I will do my best. One can find an even more detailed version of the theory in Smolin (2020). What follows is material from the book as well as a brief summary of his fundamental theory from the paper in question (see p. 24, 2020, for a brief summary).

A new ontology is proposed according to which the universe consists of a dynamically evolving collection of partial views of itself. This is the causal theory of views. This theory originates from causal set theory, wherein, given a certain set of rules, all other properties and entities in nature are to be derived from a large discrete set of events, on which are defined only causal relations (which event causes which). In the causal theory of views, "the beables are the information available at each event from its causal past, such as its causal predecessors and the energy and momentum they transfer to the event. We call this the view of an event. That is, we describe a causal universe that is composed of a set of partial views of itself." (2020, p. 4). Smolin says the slogan is one universe, described by many partial views.

Again, the view of an event contains information about its recent causal past neighborhood. The view also represents flows of energy, momentum and other conserved quantities. The views are the only beables of this theory. The dynamics which creates the events and guides the flow of energy on the causal links depends only on differences amongst views, and

expresses a principle of maximizing the diversity, or variety of views. This all characterizes the principle of background independence in his fundamental theory. The universe is "constructed from nothing but a collection of *views* of events, where the view of an event is what can be known about that event's place in the universe from what can be seen from that event. In other words, the beables of this theory are views from events, comprised of the energy, momentum and other conserved charges that combine to create the event, from its causal predecessors" (p. 4, 2020).

Before I say more about the dynamics of partial views, let me stop to give the reader two analogies and a metaphor that may or may not help. One obvious analogy is the way that thermodynamics emerges from statistical mechanics. In this case the causal theory of views is the analogue of statistical mechanics and what emerges, e.g., space, is the analogue of thermodynamics and properties such as temperature. Another analogy is Conway's Game of Life. In this analogy, the partial views (events) are like the cells in the game, the rules/dynamics that evolve the partial views are like the rules of the cell's temporal evolution in the game, and space and spatial relations are like the robust patterns in the game such as gliders and eaters that emerge "for free." Keep in mind the important dis-analogies here: 1) the "events" in the causal theory of views are not like cells, atoms or point particles, as they are discretized and have no intrinsic existence, and 2) the causal theory of views is pregeometric and also has no time (t) as a parameter, in the sense that Newtonian mechanics and the Hamiltonian version of QM have time.

The most apt metaphor I can think of (which is itself a metaphor from Hinduism and Buddhism about the nature of reality) is Indra's Net. Recall that in Indra's Net the various nodes/jewels are not merely interacting but still self-existent separate entities that interact to produce the whole. Rather, the existence of all the parts (the jewels or nodes) and the whole (the Net) are all completely interdependent on each other, so as to have no metaphysical autonomy whatsoever. Every jewel in Indra's Net is a microcosm of the whole that reflects or is a subset of many other jewels. In this metaphor the jewels are the events in Smolin's theory, and their reflections are the partial views. Jewels in Indra's Net are not static, they are in constant flux, analogous to the dynamics operating on Smolin's events. Indra's Net encompasses everything, there is nothing beyond it, analogous to Smolin's claim of closed causal completeness for the fundamental theory. Smolin himself makes an analogy with Leibnizian monads, but it should be clear that Smolin's monads are anything but windowless.

Let us now say a little more about the nature and dynamics of events (Smolin, p. 14, 2020):

1) No elementary event has only one cause. Therefore, there are no isolated elements of views, each view contains a number of elements unified by being part of the view of a particular event.
2) At an elementary level, the view consists of a framing, which is a two-sphere, marked with labeled points, each representing the incoming direction of each of its N_p parental causal processes (gotten from the direction of the incoming momentum), with the label taken to be a measure of the energy transmitted by that causal process of possible views, V of an event. There is a space of possible views, V of an event.
3) We can call this description of the view of an event its *sky*; it is literally what is seen looking outward (and hence back into its causal past) from the event. The views are sufficient to reconstruct the events and their causal relations as well as flows of energy-momentum. So, while we started thinking of events and causal processes, we end up with just the views as the only beables.

4) Events may be combined into sets of events, which have a joint causal past, hence each set of events also has a joint view. There is a natural algebra for combining views. Some laws act together on sets of events and their views, we call these law-bound. Entangled states and coherent states will require this treatment. These must be dealt with irreducibly.
5) The event creation dynamics knows about the views only through their differences, D (I, J). It is specified by requiring that the diversity of views is maximal.
6) In a "continuum limit" in which a spacetime emerges, together with an embedding of the discrete causal structure into it, a view must become approximated by a cross-section of a backwards light cone, (i.e., a sphere of some dimension) on which are found punctures or (coarse grained) fields, which carry energy-momentum and other conserved quantities. In our universe, d = 2. Thus a view physically is a full or partial S^2, on which live, depending on the level of description, punctures labeled by energy, momentum and other conserved charges, or pull backs of fields (into the light cone's cross-section) carrying those conserved quantities.
7) The real ensemble theory is a realist completion of QM, which, in its most general formulation, is based on the principle that the dynamical variables of the theory are differences of views of subsystems. This can be thought of as a norm or distance function D (I, J).
8) On a theory with many subsystems, S_I, each of which has a view of the others: v_I^J represents the view of the subsystem J from the subsystem I. The subsystems may also be composites and have internal degrees of freedom y_I^α, that also are seen in the views.
9) In this world a fundamental role is played, not by distances in a background space, but by differences between pairs of views. We will then employ D(I,J) as a measure of difference of two views, I and J, i.e., a distance function on a space of views, S.
10) The dynamics has two parts. There is the event generator, which picks the parents of each newly created event. Then there is an action principle which determines how the energy and momentum are distributed to the recently formed events.

I cannot possibly unpack everything Smolin says here in a book review, I only wish to impart the essence of Smolin's view to the reader.

Some of the consequences of this view are as follows (Smolin, 2020, p. 24):

- The replacement of locality (in a background space) with similarity (in a space of views) has striking consequences. Since space is emergent, so is locality, and the mechanism by which that happens is that much of the time the world is arranged so that locality in the emergent space tracks similarity of views. (Come here and look at what I see!) *But locality, being emergent, will have defects, where two very similar views represent two events which are very far from each other in the emergent spacetime geometry* [my emphasis]. This leads to the recovery of quantum mechanics. The key point is that a small composite system, like an atom or a small molecule, will have *copies* which are scattered across the universe. These nonetheless interact strongly with each other. When there are many copies, the evolution develops sufficient coherence and the result is unitary Schrödinger dynamics.

- This suggests a new picture of evolution in quantum physics, which I called the principle of precedence. A quantum state evolves because the underlying dynamics being local in the space of views, is coupled to the members of an ensemble of similar states in its causal past. These are its precedents, and the proposal is that quantum dynamics is simply the copying of random precedents from a state's causal past.
- When a subsystem is too complex or large, it will not have any copies in the universe, so it is not a part of such a large ensemble. Hence, they do not correspond to pure quantum states. These are the novel states. *Their evolution law is not the Schrödinger equation, but a more complex non-linear equation, governed by the full dynamics of the completion* [my emphasis]. The dynamics is specified by the same theory, but without taking the large M limit or constructing an ensemble and its probability distribution. *This is, we may note, a solution to the measurement problem, because macroscopic devices, clocks, ourselves and our cats all are unique and have no copies, hence are not described by a wavefunction* [my emphasis].

We have a sense now of how Smolin hopes his account will explain entanglement, non-locality and resolve the measurement problem. Let us return to the three key features of time as experienced.

Smolin (see for example 2013) focuses on time so much in part because our experience of time is central to everyday experience generally and thus, he expects fundamental physics to explain temporal experience in a way that does not violate his naïve realist desiderata. As he puts it:

> It has been noted before that if one takes a realist attitude towards qualia and conscious experience one is pushed towards embracing time [Passage] and the present moment as real. One way to say why is that there are two aspects of nature that are not capturable in a purported identification of the history of the universe with a timeless mathematical object. One is the present moment, the other is a conscious sensation. And indeed they seem related because every sensation is contained in a present moment (2020, p. 11).

Let us begin with Passage or Flow, "Bring in time, and let us take the view that the present moment and the flow or passage of moments are real and fundamental…There is an objective distinction between past, present and future. The present consists of events which have happened, but which have yet to give rise to the future events that will be their replacements" (2019, p. 200). This isn't quite presentism or growing block perhaps, but he does say that the past has the structure of a causal set. We can also infer from Smolin's principle of precedence that while possibilities are constrained, the future is open in that there can be novel or unique configurations of events that arise. Again, one can't help but think of statistical mechanics wherein there are likely and unlikely configurations of atoms and molecules. However, unlike statistical mechanics, Laplacian determinism fails in Smolin's theory. Why is that so? That is, wildly improbable events are still consistent with determinism, so that can't be the answer.

Presumably the idea here is that our everyday experience of Passage or Flow is explained by the dynamical evolution in this pregeometric realm of events (partial views). Again, modulo his claim about a preferred frame, keep in mind that unlike classical mechanics and Hamiltonian QM, there is no universal parameter t in Smolin's fundamental theory. In this way

his fundamental theory is more like GR. However, unlike GR, his fundamental theory is pregeometric!

What about Presence? Smolin might say that Presence is explained by the "growing edge" or accretion of new events in his fundamental theory or by his preferred global reference frame. In Smolin (2020) he calls this issue the "presentism problem", and defines it thusly, "Why does that scene bundled together represent, approximately to be sure, a thickened (i.e., of some small duration) moment of time" (p. 7). Thus, instead of merely giving us a correlate in his fundamental theory to explain Presence, he invokes a unique version of panpsychism. As he describes it, "There are no 'atoms of experience', i.e., experiences of nothing but a shade of red or blue or a pure high C. *Each conscious perception comes as a complex but irreducible unity, which may contain a number of qualia, thoughts, sounds, smells, all together, defining a (thick)moment of time, always in a frame, which is often experienced as a two-sphere, or a piece of one.* We call this a *framed conscious perception*" (Smolin, 2020, p. 17).

Smolin's brand of panpsychism is unique in that only views of novel events or novel law-bound sets of events are correlates of conscious perceptions. Novel events are those that have no near precedents in their causal past. Standard panpsychism proposes that there are qualia (or proto-qualia) associated with all fundamental physical states or processes. Smolin's view proposes that there are framed or bundled conscious perceptions, associated to a very restricted subset of view—those that are novel and maximal. More specifically Smolin's brand of panpsychism has the following features (2020, pp. 24-25):

1. Each framed conscious perception corresponds to the view of a physical event or law-bound sets of events.
2. Common events, which are those whose views that have many near copies, are those described to good approximation by quantum mechanics as formulated. These are not correlates of conscious perceptions.
3. Only views of unique events or unique law-bound sets of events are correlates of conscious perceptions. The idea is to construct composites of views, which are themselves views.
4. Only the top level of each hierarchy of ensembles of views are correlates of conscious perceptions. These are the first levels in the hierarchy which are unique single views, with no near copies.
5. Different qualia of the same modality (i.e., colors, tones) correspond to differences in energy.

According to Smolin, the "presentist problem" is addressed because, "each framed conscious perception is associated to a single event or, to a law-bound set of events. In the latter case, the moment may be thick" (2020, p. 18). That's all there is to it according to Smolin. He doesn't come out and put it this way, but Smolin is really replacing the idea of qualia (discrete tropes of experience such as 'seeing red') with subjectivity—there are no experiences without subjects, and their perspectival points of view are associated with events that have some duration (they are not point-like). This sounds a great deal like the idea of an extended specious present but applied to Smolin's unique events.

Finally, what about Direction? Here is what he says:

> An event is something that happens…Once something happens it cannot *un-happen*…once an event has happened it is in the past, and that fact cannot be erased by a future event…Each past event has a causal past, consisting of those prior events that have directly or indirectly influenced it…Once an event as had its full allotment of children [exhausted its causal influence], it may no longer play a direct role in creating the future (2019, 266).

It would seem then that the Direction of time is just a brute fact in Smolin's theory.

Concerns and Criticisms

We have enough on the table that we can now start asking more questions and raising more concerns. Before I do that let me say this in order to make clear the spirit of my remarks. Regardless of one's views on the realism/anti-realism debate and the purpose and scope of physics, most of us can agree that theoretical physics has hit a wall. It's true that we are all still struggling to determine what QM and relativity are telling us about the nature of reality (e.g., should we be realists about Minkowski spacetime? What is gravity? How should we think about gauge invariance? Etc.). We can also agree that we would dearly like more empirical clues in order to help resolve such questions. However, while underdetermination in QM and relativity might abate somewhat, it is never going to disappear, so perhaps this isn't the end of the world. However, the more damning concern is that theoretical physics seems not to be a progressive scientific endeavor at the moment in the way it was during the birth and early development of QM, QFT and relativity. We simply have nothing like those revelatory revolutions going forward. Confirmation of the Higgs field and gravity waves are great achievements, but those predictions were made decades ago.

If one thinks back to the debates between high energy physicists such as Weinberg and condensed matter theorists such as P. W. Anderson, it is not hard to see that the condensed matter theorists were right in their prediction that their field would be the future of physics. I don't think a superconducting supercollider encircling the planet would have changed that outcome. Anderson and others warned that moving to ever smaller scales and higher energies in search of ever 'deeper' explanations, would make clear predictions, confirmation and disconfirmation, etc., ever more elusive. After all, they pointed out, QM is for all practical purposes the fundamental theory of most everyday phenomena we encounter and even there, ab initio derivations are nigh impossible, e.g., getting molecular structure from the Schrödinger equation. So, it isn't surprising that the state of QG is what it is now.

Yet, we all agree a theory of QG of some sort is needed for many reasons, and we all agree that more insight into QM, relativity and their unification might yield the clues we need for the next great revolution in physics. Most of us agree that some previously held axiomatic assumptions must be false, e.g., the completeness of QM in Smolin's case, and most agree that we need to explore other novel axiomatic assumptions in order to make progress (e.g., the QIT project). Smolin and others are doing their due diligence to do exactly this. That is, we are all placing our methodological and metaphysical bets and hoping to make progress. Thus, I applaud Smolin for boldly adopting a direction and pursuing it with conviction. However, while I agree with some of Smolin's basic principles and assumptions, I worry about others. These worrisome assumptions are shared by many in the field of QG and I suspect they need to be questioned.

In what follows I will raise questions and concerns for Smolin's program in the hopes of trying to get him to question some of these assumptions. Normally, I would hold out little hope for such an endeavor, as in this business we all tend to be religious in our convictions. Witness the debates between defenders of different interpretations of QM for example. However, I do have some hope in this case because Smolin has always showed himself to be open minded and open to dialogue. Thus, my primary goal here is not destructive or pugilistic, I'm also motivated by the desire to make progress. At the very least, hopefully something I say will suggest to Smolin a way to make his program tighter. Better yet, hopefully something I say will spark a fruitful dialogue.

Here then are my major concerns and questions:

Q1. Does Smolin's fundamental theory fare much better than alternatives as an exemplar of naïve realism?

First, Smolin's naïve realism is clear that the beables in the fundamental theory ought to be relatively quotidian and non-exotic, unlike, say, the unitary evolution of the universal wavefunction in Hilbert space with its indenumerably infinite branches. The problem is that the only beables in Smolin's theory, the views (the events), are nothing like the physical objects we encounter in everyday experience or even physics. Views do not seem like constructive, constitutive, causal-mechanical entities in the way that particles, fields and waves sometimes do; no *physical* picture, analogy or metaphor even comes to mind here for his beables.

Second, the beables in Smolin's theory are radically contextual, hence my Indra's Net analogy. The contextuality in Smolin's theory makes the contextuality of Bell and KS look like Democritean atomism by comparison. Smolin's beables don't seem like the kind of hidden variables that complete QM in the sense of removing the weirdness of contextuality and non-locality, rather, they double down on these features.

Third, Smolin is clear that beables and the laws governing them ought to be empirically accessible, observable in some sense, manipulatable, make clear predictions, etc. But what could fail this test more than pregeometric partial views? We can't even assign such beables a length and time scale, let alone detect them in any way. Again, how do we even begin to do the physics of Indra's Net? It is hard to see how we could use Smolin's fundamental theory to model an experiment or anything else of significance in spacetime. Another way to make this point, it isn't clear what Smolin's theory tells us happens between source and detector in a QM experiment in spacetime. For example, what does Smolin's theory entails is happening physically in the twin-slit experiment? Why is there an interference pattern at the end? Is Smolin a realist about the wavefunction? Particles? Fields? If so, what are they exactly and how are these entities recovered from his fundamental beables?

The point is that, from the perspective of Smolin's naïve realism, his fundamental beables just don't seem like physics or physical entities. It isn't clear why his beables are any less "magical" than those of the Many Worlds interpretation, or any less abstract or "radical" than those of information-based accounts. Recall, the beables on Smolin's view just are the information available at each event from its causal past, and the flow of information defines a causal structure (2019, p. 260).

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Smolin's invocation of panpsychism also seems like a stretch for his brand of naïve realism wherein observers and subjects should have no special place in physics. If the idea is that physics and physical processes would be utterly unaffected were conscious experience or subjectivity to vanish, that doesn't fully comport with Smolin's version of panpsychism. If subjectivity, even if epiphenomenal, is the intrinsic or essential nature of a key set of fundamental physical beables, then we can hardly say that there is nothing perspectival in fundamental physics. Furthermore, one assumes that were this intrinsic and essential subjectivity to cease to exist, that would by definition effect the existence of that particular set of physical beables. As Smolin says himself, "Indeed, Penrose and Hammeroff, Chalmers and McQueen, Gambini and Pullin, and others have already put forward proposals for *how consciousness may play a role in the domain of possible completions of quantum phenomena* [my emphasis]. The proposals I make here are similar" (2020, p. 9).

Smolin thinks his version of panpsychism has an advantage in this regard because, as he puts it, "The monist step of seeing qualia as aspects of physical processes seems promising. It is the assumption that the correspondence is universal that seems to land us in trouble" (2020, p. 6). Smolin thinks that if we limit the association of subjectivity to a restricted subset of physical processes based on purely physical principles, then panpsychism becomes less problematic and less odious. However, the worry is that if subjectivity or proto-subjectivity is not universally the intrinsic essence of fundamental beables, but only arises under certain conditions, then this isn't really panpsychism at all, it's more like strong emergence, the dreaded enemy of panpsychism. One major argument for panpsychism is that it provides the intrinsic essence of matter that is not given by mere physical dispositions. Smolin cannot avail himself of this argument or claim this advantage if panpsychism isn't universal. In short, I do not think that non-universal panpsychism is a stable position.

Furthermore, the very idea of panpsychism violates the quotidian commitment of naïve realism. As many have noted over the years, it is hard to imagine anything less warranted to believe in, less observable and less confirmable than panpsychism. Panpsychism is a gross violation of commonsense realism. As Goff puts it, "The main objection made to panpsychism is that it is 'crazy' and 'just obviously wrong'. It is thought to be highly counterintuitive to suppose that an electron has some kind of inner life, no matter how basic, and this is taken to be a very strong reason to doubt the truth of panpsychism" (2017).

Nonetheless, as Smolin notes, a growing number of philosophers and physicists think some brand of panpsychism is the best hope to preserve at least the spirit of physicalism, i.e., the idea that all fundamental facts reside in fundamental physics. I confess that whenever I hear this claim, I am gobsmacked. After all, another standard way of defining physicalism is that nothing mental can be fundamental. At any rate, given the increasing skepticism about identity theories and strong emergence and given the explanatory ambitions of physics, they clearly feel forced in the direction of panpsychism. However, is panpsychism really a kind of monism, let alone a kind of physicalism?

People often say, Smolin included, that panpsychism is a kind of monism. However, panpsychism holds that what is fundamental is both inherently physical and mental. Panpsychism and the like holds that mental and physical properties are both dependent on each other in some way, for example, as Penrose puts it: "that the phenomena of consciousness and of quantum-state collapse may each have something deep to say about the other" (1989, p. vii). Thus, both strong emergence and panpsychism entail a kind of property dualism, even though

strong emergence claims to be a kind of physicalist monism and panpsychism claims to be a kind of dual-aspect monism. Calling something "dual-aspect monism" is just another name for property dualism unless one turns it into a fully-fledged version of neutral monism.

Strong emergence definitely requires brute psycho-physical bridge laws or brute utterly novel causal processes, and panpsychism might also if no physical law or process such as QM entanglement can do the trick to resolve all the combination problems. That is, how do fundamental physical beables with their proto-subjectivity combine or otherwise manage to generate fully unified conscious beings such as ourselves? Strong emergence in its brain-based form assumes the bridge-law or novel emergent causal process in question will be tied to biological processes and panpsychism hopes to find some bridge-law or weakly emergent causal process grounded in fundamental physics itself. However, even panpsychism admits there is something special about brains or perhaps other information processing systems that explains why we only see unified minds such as our own at such spatiotemporal scales. That is, panpsychism acknowledges that animal consciousness is very much a product of biological evolution and, just like strong emergence, must still explain why. So perhaps the most notable difference between strong emergence and panpsychism is that the latter hopes to get away with nothing more than weak emergence, having given itself proto-consciousness as fundamental. If that turns out not to be enough, then panpsychism is without motivation; this is a serious concern as of now because some combination problems threaten to become hard problems, e.g., they threaten to require brute psycho-physical bridge-laws a la strong emergence.

In short, strong emergence and panpsychism are both just versions of property dualism, thus making it harder to explain the various connections between mind and matter. Both views are just patches for physicalism or materialism, and neither view advances physics in any way. Both views are driven by the dynamical/constructive bias when it comes to explaining conscious experience. Strong emergence assumes that some brute psycho-physical bridge law or some brute novel causal process must be posited to explain the POPPING of mind from mere matter. Panpsychism looks to some new dynamical law or causal process such as QM or panpsychist "fusion" to solve one or more combination problems. Strong emergence has its brute psych-physical laws/causal processes and panpsychism has its brute proto-qualia/proto-subjectivity and yet still requires some (perhaps completely new) kind of dynamical or causal processes to explain the existence of unified conscious minds such as our own.

Panpsychism claims as an advantage over strong emergence that the origins of consciousness or proto-consciousness is in fundamental physics. The panpsychist thinks it should be comforting to us naturalists to associate consciousness with fundamental physics. I am deeply puzzled by this intuition. For me, panpsychism doesn't make proto-qualia/proto-subjectivity any less weird, on the contrary. At least associating conscious minds with brains makes some intuitive and empirical sense; after all, there are many important dynamical and causal relationships between brain states and conscious states. Rather, panpsychism only makes matter weirder and seemingly less natural. It's like learning that there are fairies in the world, but then being told to relax because we have decided they are just brute features of fundamental physics. How does this help us feel better about either physics or fairies? The truth is, if what one appreciated about physicalism or ontological reductionism was the beauty and simplicity of explanatory and ontological unity, strong emergence and panpsychism are both gross disruptions to that picture of reality. Frankly, either view disconfirms the idea that matter traditionally understood and physics alone is fundamental. Substitute immortal souls for fairies and the point is clear, the mere act of putting conscious experience or subjectivity into

fundamental physics doesn't magically turn "qualia" or subjectivity into a physical property like momentum. Remember, the whole idea behind physicalism and materialism is to reduce or identify mental properties with biological ones or physical ones, not give them equal billing.

Smolin also says that, along with proto-subjectivity, energy and momentum are fundamental and intrinsic as well (2019, p. 261; 2020, p. 13). While Smolin certainly has conjectures about how "energy" and "qualia" relate, the bigger issue here is why does Smolin think it's okay to give himself energy and momentum as fundamental, but not space or time as a parameter? I'll return to this question later but given his brand of methodological reductionism and method of unification, one might worry that giving oneself subjectivity, energy and momentum is cheating. And if it isn't cheating, then what exactly determines what one can give themselves without cheating, in the game of QG?

Q2. Does Smolin's fundamental theory explain the key phenomenal features of time in keeping with na ̈ve realism?

Let us start with Passage or Flow. The key question is why should one believe that "causal" processes in a pregeometric realm with no space or time as a parameter actually explains or corresponds with our everyday experience of Passage? How would one even go about establishing such a claim? Indeed, even though Smolin says "time" as "causation" is fundamental, what do these words mean in his fundamental theory? I would suggest that Smolin's fundamental theory or anything like it, only makes it harder to explain the experience of Passage. For example, Schneider raises a worry for panpsychism based in the fact that our current best theories of quantum gravity, such as Loop Quantum Gravity (LQG), are radically timeless, even more so than the eternalism or block universe associated with relativity (2018). As Rovelli writes of LQG, "the theory does not describe how things evolve in time. The theory describes how things happen in the world in relation to each other. That's all there is to it" (2018, p. 7).

The reader might wonder what makes LQG any worse in this regard than general relativity (GR). Assuming that one is a realist about Minkowski spacetime, it's true that in relativity theory the relativity of simultaneity makes the ordering of events into past, present, and future frame dependent. Nonetheless, the spacetime interval and light-cone structure evidence things observers in different reference frames will agree on, such as the causal ordering of events (modulo faster than light influences). But, as Rovelli notes (2017, p. 125), "LQG does not have the curved and smooth geometry studied by Einstein. ... We cannot draw a complete map, a complete geometry of everything that happens in the world, because such happenings–including among them the passage of time–are always triggered only by an interaction with, and with respect to, a physical system involved in the interaction. *The world is like a collection of interrelated points of view* [my emphasis]. To speak of the world 'seen from outside' makes no sense, because there is no 'outside to the world.' " It should clear that Rovelli's take on LQG and Smolin's theory of QG have much in common formally and otherwise.

In LQG the fundamental events described by the theory (e.g., the spin network "interactions") are simply not ordered in time, as they are even in relativity. That is, relativity is grounded in the very idea of being able to always coherently relate all observers' reference frames so as to talk about interrelated points of view (e.g., the relativity postulate, the equivalence principle, Lorentz transformations, the spacetime interval, etc.). But, in LQG the "points of view" (whatever that even means in a pregeometric context) will NOT be coherently interrelateable.

LQG entails a kind of solipsism, at least at the most fundamental scale. The world of LQG has nothing like the time we experience on a daily basis and for that matter, it doesn't have space or things (i.e., transtemporal objects) either. Space has to emerge somehow and matter (e.g., energy and momentum) has to be put in by hand. Kant would say that LQG "violates the bounds of sense."

No matter what one's position on the metaphysics of consciousness, LQG is going to have a very, very hard time explaining our everyday experience of time and change. However, Schneider's worry for panpsychism in particular is that if LQG or something like it is fundamental, then panpsychism is committed to proto-qualia or proto-subjectivity being associated with, say, spin networks. But since conscious experience is by nature temporal and spatial, it is hard to see how spin networks could be having experiences of any sort, or how unitary everyday spatiotemporal experience could "emerge" from such processes. As she puts it, "How does experience, which is so intimately tied to our perception of time and space, arise from timeless, non-spatial ingredients?" (2018) As she correctly notes, panpsychism can't say that the passage of time is an illusion explained by some non-experiential feature of physics or neural processes, because for panpsychism experience of some sort is fundamental and experience is inherently temporal. As she says, "If the more fundamental ingredients of reality are non-spatiotemporal, it is difficult to see how they can also be experiential, or if there is no time at this level, how could there be experience? Conscious experience has a felt quality that involves flow" (2018).

Goff, noting Schneider's worry about LQG-based panpsychism, makes the suggestion that maybe we could marry up the mystics' claim that fundamental reality is an inherently timeless pure presence or Nowness with LQG, such that "If–I emphasize the if one last time–the insights of mystics are correct that formless consciousness is an essential component of each and every conscious experience, then–in conjunction with panpsychism–it follows that formless consciousness is an essential component of each and every physical entity" (2019, p. 210). But how does this suggestion allay Schneider's worry, especially if we stick to LQG? That is, how are we going to get the everyday experience of temporal passage out of pure presence plus spin networks? Just as Schneider says (2018):

> Upon reflection, spacetime emergence seems to make the hard problem even harder. For how does conscious experience, which is so intimately tied to our perception of time and space, arise from timeless, non-spatial ingredients? Put another way, how does experience stem from the non-spatiotemporal ingredients such as those that loop quantum gravity says underlie tiny quanta of volume, or that string theory says underlie the fields on a surface traced out by a string or loop?

As far as I can tell, everything said here about LQG imports over to Smolin's causal theory of views. Indeed, in Smolin's fundamental theory there is no time as a parameter, no causal or nomological necessity, there is only Humean change in the sense that the events always have the structure of a causal set but with different arrangements, are related via something like a directed acylic graph, etc. Again, why would anyone think this explains the everyday experience of Passage?

What about Presence? Again, there is nothing like Presence or Nowness in Smolin's fundamental theory. There is nothing like a spotlight or some other metaphysical mechanism or pointer that yields Presence, i.e., no mechanism that tells us which event are really NOW

such that we experience them as special. There are even fewer resources in this regard than one finds in relativity, as Smolin's fundamental realm is pregeometric. Smolin does invoke a global preferred frame but it isn't clear how or why that emerges from his fundamental theory or how it would explain Presence even it exists. His explanation of Presence requires panpsychism with perception, memory, etc., being structured and ordered in a certain way. This is the idea of a specious present. But one is free to adopt such an explanation without invoking either panpsychism, QM physics or a pregeometric realm. There are many similar accounts of Presence (and Passage for that matter) that merely invoke certain thermodynamic patterns, neural mechanisms and cognitive structures, e.g., the IGUS account (see Callender 2017 for details).

Why is there Direction? Why is the pregeometric realm time-asymmetric? The answer I gather is that it just is. Direction is definitely fundamental, a brute fact in Smolin's account. As he says, events are irreversible by definition: "In these ontologies time is fundamental and irreversible" (2020, p. 11). But again, the question is even if we just accept this as a brute fact about the pregeometric realm, how and why does this translate to Direction in the world of experience in spacetime? Or does it? After all, there is nothing in QM or relativity, or even thermodynamics that *entails* time must always be asymmetric. Indeed, the first two are in fact generally regarded as time-symmetric in principle. As we all know, the standard statistical explanation for Direction based in the second law of thermodynamics only begs the question as to why that particular initial condition at the big bang. Furthermore, many of us have argued that said explanation for Direction actually presupposes time and doesn't explain it.

Smolin is duty bound to explain the big bang given his commitment to a causal version of PSR. He has certainly speculated on cosmological mechanisms for producing multiple big bangs, but I don't yet see how such explanations are grounded in his more fundamental theory. Smolin's goal is to construct a cosmological theory that is never stuck with questions such as, "why *those* initial conditions at the big bang?"; contrary to the way that standard dynamical explanations and theories such as GR are stuck with that question. How can he make good on that goal while maintaining his commitment to PSR? Even if one invokes a cyclic cosmology, given PSR, what stops someone from asking, "But what caused that cyclic cosmological mechanism to exist?" Smolin is clear that his commitment to causation as fundamental precludes closed-causal-loops and closed time-like curves. Indeed, given a causal version of PSR, when and how can one ever be justified in their belief that they have hit metaphysical and explanatory bedrock? For example, what stops one from asking, "But what caused the pregeometric realm of beables and their dynamics to exist?"

Q3. How plausible is it that Smolin can recover spacetime or matter from nothing but his fundamental pregeometric theory?

Many of the concerns I'll raise in this section are not unique to Smolin's fundamental theory. Indeed, in fairness let me remind the reader of the state of QG in general:

> All these approaches [to quantum gravity] have their share of problems and challenges; especially, each has at best remote and tenuous connection to experiment, and so there are only weak empirical constraints on theory construction and choice (Huggett et al., 2013, p. 244).

The confirmation and empirical constraint worries are a universal problem for all current accounts of QG, but regarding what Huggett, Vistarini, and Wüthrich call the "truly iconoclastic" accounts of QG, such as *causal set theory* and causal dynamical triangulation, things are even worse:

> Members of this family tend to offer programmatic schemes rather than full-fledged theories. They gain in attraction as more conventional approaches [string theory and loop quantum gravity] fail to produce a complete and coherent quantum theory of gravity (Huggett et al., 2013, p. 244).

The more damning concern is that, aside from their problems in the high energy cases, no program of QG convincingly recovers the low energy physics of GR, QFT or both:

> The second reason for the absence of consensus is that there are no experiments in quantum gravity, and little in the way of observations that might qualify as direct or indirect data or empirical evidence. This stems in part from the lack of theoretical predictions, since it is difficult to design an observational test of a theory if one does not know where to look or what to look at. But it also stems from the fact that most theories of quantum gravity appear to predict departures from classical relativity only at energy scales on the order of 10^{19} GeV. (By way of comparison, the proton-proton collisions at Fermilab have an energy on the order of 10^{3} GeV.)
>
> *However, it should be noted, finally, that to date neither of the main research programs has been shown to properly reproduce the world we see at low energies. Indeed, it is a major challenge of loop quantum gravity to show that it indeed has general relativity as a low-energy limit, and a major challenge of string theory to show that it has the standard model of particle physics plus general relativity as a low-energy limit* (Weinstein and Rickles, 2016, p. 501).

In other words, programs in QG fail to recover spacetime, matter or both in any compelling way. As Rovelli puts it:

> A theory begins to be credible only when its original predictions are reasonably unique and are confirmed by new experiments. Neither loop quantum gravity nor string theory—nor any other tentative theory of QG—are yet credible in this sense. Furthermore, in spite of much effort, both theories are still badly incomplete and far from being clearly understood. The problem of QG must therefore be considered still fully open (2007, p. 1302).

The truth is we have no earthly idea how to recover the world of everyday experience, QFT or GR from pregeometric starting points, not without cheating anyway. Recall our earlier discussion of LQG. It is an amazing irony that our reductionist assumption that all fundamental explanation must be at the smallest scales (and beyond spatial scale to the pregeometric) and highest energies, coupled with our dynamical/constructive causal explanatory bias, leads us to LQG and other related pregeometric models in QG that are radically timeless, spaceless, or matterless. Why are we in this situation?

In the last section I pointed out that Smolin just gives himself matter, i.e., energy, momentum and indeed all conserved quantities. I queried as to whether this was cheating in the game of

QG. His reply is that there are only two games in town in QG (2019, p. 237). The one he embraces ("temporal relationalism") starts with something time-like and tries to recover space. The other alternative ("eternalist relationalism") starts with something space-like and tries to recover time. He believes that temporal relationalism has the following consequences:

> Further, we have hypothesized that space is not present at the fundamental level in nature, but is emergent. So if we want energy and momentum to play a role in physics, there seems to be no alternative but to put them in at the beginning…So we are left with a picture in which causal relations, energy and momentum are fundamental (2019, pp. 264-65).

Smolin believes, "the result is that a coherent spacetime emerges only in models in which [a global] time is assumed to be real" (Smolin, 2013, p. 189). As a result of these and other considerations, Smolin concludes that "space may be an illusion, but time must be real" (Smolin, 2013, p. 192).

Let us set aside the cheating question. Does it even make sense for momentum and energy to be fundamental but not space or time as a parameter? Based on the definitions of momentum and energy in classical and quantum mechanics, the answer would seem to be no. More generally, can one really define or recover things, time or space respectively without adverting to one or more of the other concepts? For example, Smolin talks about *multiple events/beables* with their respective views, but how can we distinguish events without spatiality? This would be a violation of a version of Leibniz's law: multiplicity IFF discernability (MID). There cannot be multiple events without spatiality. This just seems like a matter of logic.

I have no knock down no-go argument that a pregeometric recovery of QFT and GR is impossible. However, I strongly suspect that things, time and space are by necessity co-definable only and thus co-fundamental. Take the following standard definitions (or partial definitions) as an admittedly informal proof:

> Thing: To be a thing is to be identical to itself over time—the same thing at two or more different times (i.e., thinghood is transtemporal identity). Thus, you cannot define thinghood without invoking time. And we already established you cannot define a thing (a single independent object) without invoking space.

> Time: In order for there to be time, there must be things with transtemporal identity that manifest changes at different points in space. Thus, you can't define time without invoking thinghood and spatiality. Time is a construct of apparent identity from multiplicity, i.e., I am the same person now as when I started college.

> Space: In order for there to be space, you have to invoke different things existing at separate locations. So, you can't define space without invoking things. Space allows for multiplicity in the face of apparent identity (e.g., electrons that are identical except for their spatial location), because as we already noted, multiplicity obtains IFF discrimination is possible.

Thus, I'm not convinced it makes sense to have a fundamental *physical* theory that is absent time, space or thinghood and recover all the rest as we experience them.

There is no doubt that even in a purely graphical formalism with nothing but edges and nodes, one can define all sorts of purely graphical notions of nearness/space, causation (e.g., certain kinds of directed graphs or causal sets, Granger causation), etc., without invoking or referring to anything geometric. However, the question is how can one possibly recover the everyday notions of thing, space and time/causation as experienced from the purely graphical realm? For example, for any given graphical structure there will be infinitely many metrics consistent with it.

Let me be clear that none of this is an argument for substantivalism about space, time or things. As illustrated above, I am a thoroughgoing relationalist about all three. I am actually quite surprised that Smolin is not more of a relationalist about time as well given his invocation of GR as his guiding theory, because GR is based on the very idea that one cannot meaningfully discuss or define things, space and time separately. The stress-energy tensor (SET) in GR describes the matter–energy–momentum distribution in spacetime. Thus, in order to provide the elements of the SET you have to know spatial and temporal distances for momentum, force, and energy. Of course, knowing spatial and temporal distances means you already know the metric. Therefore, you should view Einstein's equations as providing a self-consistency criterion or a "global constraint" between what you mean by spatial and temporal measurements and what you mean by momentum, force, and energy. One must find a metric *and* stress–energy tensor (SET) on the entire spacetime manifold M in order to have a GR solution. Any combination of the metric and SET that solves Einstein's equations on the spacetime manifold M constitutes a solution of GR. Thus, Einstein's equations are best viewed not merely or primarily as dynamical equations of motion, but as a global constraint, that is, a self-consistency criterion for the metric and SET on the spacetime manifold M. This is why GR is a background independent theory. GR itself is the best reason to believe that thing, space and time only make sense as an inter-definable package. There is nothing about GR that suggests time is some sort of exception.

Back to The Future

Let me stress again that theoretical physics is at an impasse and no one knows what to do. As illustrated herein, there is simply very little consensus or agreement. For example, it is worth noting the irony that in the past two decades, just as some have sought a principle explanation of QM, others have sought a constructive explanation of SR (Brown, 2005, Brown and Pooley, 2006). Metaphysically and methodologically, one can find nearly any program and its opposite out there in the foundations of QM, QFT, relativity, and QG. We are all doing our best to move forward and of course most roads will be dead ends; nonetheless, someone has to traverse them. Smolin says there are only two ways to go:

> We either bet that we know all the fundamental principles, or we bet there are basic ideas and principles missing…When it comes to quantum mechanics we face the same choice. Either we bet that we have the complete theory in our hands and just need to understand it better, or we bet the theory is incomplete in important ways. The Copenhagen interpretation, the operational interpretations, Everett quantum mechanics, and so on are all ways of betting we know everything important about quantum phenomena. Anyone who focuses exclusively on one of the realist proposals such as pilot wave theory or spontaneous collapse is betting their favorite theory will turn out to be the correct completion of quantum mechanics. In either case, the bet assumes that we know all the principles needed to understand nature (2019, pp. 274-75).

Here Smolin is offering us a choice between accounts of QM that don't alter the theory formally in any way, which he dubs "anti-realist", and those accounts that do alter the theory formally, which he dubs "realist." I want to end my review by questioning whether perhaps this choice and others that Smolin invokes represents a false dichotomy. I agree completely with Smolin that our fundamental physical theories ought to undergird and explain everyday experience and not render it an illusion or deception, thus undercutting the very basis for doing physics in the first place. However, as argued throughout, I don't believe that Smolin's naïve realism and his fundamental physical theory are compatible.

My suggestion is that we might make progress in theoretical physics/foundations and with reconciling fundamental physics with everyday experience, if we are willing to let go of certain false dichotomies. I believe the following 'antinomies' invoked by Smolin are such false dichotomies:

1. Embrace a thoroughly "anti-realist" or "realist" account of QM (as he defines those terms).
2. Embrace a purely Heraclitean (time/Passage is basic) or purely Parmenidean (space is basic) fundamental theory (i.e., QG).
3. Embrace the idea that all fundamental facts (such as the basis for our temporal experience) are in the domain of fundamental physics (the pregeometric in Smolin's case) or give up on unification.
4. Embrace some form of property dualism such as panpsychism or give up on realism about conscious experience.

So, what are the alternatives? In the case of number 1, instead of taking QM at face value or altering the formalism, perhaps what we need is a different perspective on what QM is trying to tell us. QM is complete but needs to be properly understood. Perhaps there is a realistic psi-epistemic rendering of QM wherein entanglement and the like are explained locally, in a purely principle fashion. Perhaps QM and relativity are trying to tell us that constructive, causal and dynamical explanations are not always fundamental. This is not so very different than Smolin's "disordered locality" once the constructive and dynamical bias is removed. Rather, some things are best explained in a principle fashion via adynamical 4D-global constraints. Let us take seriously the possibility that the Lagrangian way of looking at QM is fundamental. Unlike Smolin's own alternative, this does not require claiming that QM breaks down at some point, a claim for which all evidence is to the contrary. For such an account see Stuckey, Silberstein and McDevitt (2015 and 2016c); Silberstein, Stuckey and McDevitt (2018); and Stuckey, Silberstein and McDevitt (2019 and 2020).

In the case of number 2 and number 3, perhaps we should seek a theory of QG that isn't pregeometric, but one that begins and ends in spacetime (or at least discretized spacetime). In the spacetime of relativity as illustrated by both SR and GR, one can do justice to both Heraclitean and Parmenidean intuitions. In spacetime one can permit both principle and constructive explanations. In spacetime one need not accept that either time or space, but not both is basic. Let us take seriously the possibility that spacetime (or discretized spacetime) is fundamental. There are a few things to note here. First, given Smolin's affection for GR as a guiding theory, he ought to at least be willing to consider this possibility. After all, there is nothing in physics that demands the theory of QG must be pregeometric, thus violating the very idea of spacetime. Second, one can acknowledge that the fundamental theory must be discrete without taking on all the other baggage and weirdness of QM, e.g., Regge calculus and

lattice gauge theory. Third, claiming that spacetime is fundamental doesn't entail substantivalism. That is, it doesn't entail that were all the mass-energy to be sucked out of the world that there would still be some M4 geometric structure sitting there. And like wise with GR, it doesn't entail that the null solution represents anything real in physical reality. For such an account of QG see Silberstein, Stuckey and McDevitt (2018, chp. 6) and Stuckey, Silberstein and McDevitt (2016a and 2016b).

In the case of number 3, perhaps we pursue an account that questions the idea that smallest scale/highest energy phenomena (or pregeometric phenomena) always explain the larger scale, lower energy phenomena, but never the reverse. Let us question the foundationalism or hierarchy thesis wherein relations between the smallest scale physical entities and other larger scale physical entities are anti-symmetric, transitive, and anti-reflexive. It is time to cast doubt on the idea that at bottom in reality there is some fundamental physical (or pregeometric) entity with complete metaphysical autonomy that unidirectionally determines everything else. Once one accepts contextuality as the nature of reality as Smolin clearly does, it is not such a stretch to consider the possibility that sometimes key contextual features are multiscale. Letting go of the compositional picture of reality in favor of contextuality as fundamental opens up this possibility. For example, maybe the QM and the classical are co-fundamental and co-determining. Note that this does not entail some Bohr-like view. For such an account see Silberstein, Stuckey and McDevitt (2018) and Silberstein, Stuckey and McDevitt (2020a and 2020b).

In the case of number 4, perhaps we should seek an alternative to the mental/physical property dualism inherent in both strong emergence and panpsychism, and thus in physicalism much to its chagrin. Perhaps we should seek a fully monistic theory wherein so-called mental and physical features are actually non-dual neutral aspects of a neutral base. That is, there is only one fundamental "stuff" as with monism, and it is not essentially physical or essentially mental. This view is known as neutral monism and has been defended by both James and Russell. Perhaps therefore the Galilean primary/secondary property distinction is *completely* mistaken. If we adopt such a view, the explanation for the experience of Passage for example is not to be found in fundamental physics or in neuroscience as merely a projection of the brain. If neutral monism is true, Passage is a fundamental feature of reality without being something we put in by hand in basic physics. For such an account see, Silberstein, Stuckey and McDevitt (2018, chps. 7-8) and Silberstein, Stuckey and McDevitt (2020a and 2020b).

Where does all this leave us with respect to Smolin's naïve realism? I very much share Smolin's general realist sensibility. However, I want to suggest that some of his specific realist tenants need to be questioned. First, as Smolin seems to acknowledge, I think QM and relativity are both telling us that fundamental reality (including matter, space and time) are highly contextual and relational. Once one accepts such contextuality, it ought to lead one to question other things as follows. Second, the notion of beables as hidden, distinct entities with metaphysical autonomy that are responsible for all observables is questionable. Per neutral monism, sometimes reality manifests as particle-like, field-like or wave-like, etc., depending on multiscale context, e.g., the twin-slit experiment. There are no context-independent beables, multiscale contextuality itself is fundamental. Third, constructive, constitutive and causal mechanical explanations are not always fundamental. Sometimes principle explanations a la spatiotemporal adynamical global constraints are fundamental, e.g., the light postulate, conservation laws, least action principles, etc. This isn't surprising since the contextuality in question is spatiotemporal.

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Fourth, while the world is not mind dependent or merely perspectival in the sense of subjective idealism or being conscious-observer relative, it is mind dependent in the sense of neutral monism as alluded to above. As Russell puts it, "The whole duality of mind and matter ... is a mistake; there is only one kind of stuff out of which the world is made, and this stuff is called mental in one arrangement, physical in the other" (1913, p. 15). Compare this to the words of James, "Things and thoughts are not fundamentally heterogeneous; they are made of one and the same stuff, stuff which cannot be defined as such but only experienced; and which one can call, if one wishes, the stuff of experience in general…'Subjects' knowing, 'things' known are 'roles' played, not 'ontological' facts" (1905, p. 63). The point is that when Galileo and others insisted on the primary/secondary distinction or any other kind of dualism of inner mental experience and external physical world, they doomed us to the mind/body problem and the hard problem. Such dualisms are not empirical data we experience directly, they are cognitive illusions, inductive projections of theorizing minds. The way to undo this mistake is not to merely move the location of the mysterious dualism of subject/object or self/world from brains (strong emergence) to fundamental physics (panpsychism), but to reject completely and thoroughly the primary/secondary property distinction with neutral monism.

That is, the mind and the world are one just as Kant suspected. For Kant, given his unity of apperception, time is an a priori condition for experience, no subjectivity means no time or space. Kant here is providing a transcendental analysis in mentalistic terms. This means that the dynamical character of thought/experience and the world are two sides of the same coin. Kant's transcendental arguments from *The Critique of Pure Reason* are supposed to show that we must conceive of the world in a certain way, structure it internally according to certain categories such as time, space, and causation. Those arguments are fraught with many interpretative perils and controversies, but the basic idea is that experience is possible only if some experiences are conceptualized as being of enduring objects, enduring through time and space. Likewise, to experience a world of enduring objects there must be some sense of an enduring self. You cannot have one without the other.

However, as James notes, Kant was wrong that the structure of experience is a product or projection of mental filters or categories. Neutral monism takes the world of experience out of the head and also rejects the very idea of noumena such as Smolin's beables. Kant is right however that neither subject nor object alone, but only subject-object is the basic unit of experience. Nothing is mind dependent on this view in the subjective idealist sense. All entities and their properties are extrinsic or interdependent (not mind dependent!), not just colors, tastes and sounds, but mass, charge and spin as well. Neutral monism entails a kind of direct realism. To paraphrase James, the representation of the thing and the thing being represented are one in the same. Perception is direct and immediate "acquaintance" with the world. Anybody such as Smolin who is willing to postulate panpsychism, should be happy to see that there is another way to bring physics and experience together as one without such odious baggage.

What all of this means for the experience of time is that we need not add Passage, etc., to fundamental physics nor seek its explanation as an illusion generated by the brain. Rather, Passage is a fundamental feature of the world, and that is true even in a world where principle and Lagrangian-type explanations are sometimes fundamental. Yes, the world can be both Heraclitean and Parmenidean without contradiction. It is worth noting again the irony that the assumption that constructive explanation and time/causation are fundamental, has led to

theories of QG such as Smolin's (with its panpsychism) and LQG, wherein we could not be further from our everyday world of things in space and time.

I can't say whether Smolin will think the alternative sketched above is realist enough for his taste. I hope he and other readers will explore the citations given wherein the alternative sketched herein is elaborated in detail. At the very least however, I hope to have established that there is a viable alternative to the false dichotomies that plague us. My sense is that Smolin has gone a long way toward transcending many of the standard ontological and explanatory biases of his profession, but that he and others are stymied because they are not willing to go far enough in relinquishing their metaphysical and explanatory biases. I hope to persuade him to go all the way.

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