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Time Regained!

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James Gleick

Time Reborn: From the Crisis in Physics to the Future of the Universe

by Lee Smolin

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A pregnant moment in intellectual history occurs when H.G. Wells's *Time Traveller* ("for so it will be convenient to speak of him") gathers his friends around the drawing room fire to explain that everything they know about time is wrong. This after-dinner conversation marked something of a watershed, more telling than young Wells, who had never even published a book before *The Time Machine*, imagined just before the turn of the twentieth century.

What is time? Nothing but a fourth dimension, after length, breadth, and thickness. "Through a natural infirmity of the flesh," the cheerful host explains, "we incline to overlook this fact." The geometry taught in school needs revision. "Now, it is very remarkable that this is so extensively overlooked.... *There is no difference between Time and any of the three dimensions of Space except that our consciousness moves along it.*"

Wells didn't make this up. It was in the air, the kind of thing bruited by students in the debating society of the Royal College of Science. But no one had made the case as persuasively as he did in 1895, by way of trying to gin up a plausible plot device in a piece of fantastic storytelling. Albert Einstein was then just a boy at gymnasium. Not till 1908 did the German mathematician Hermann Minkowski announce his "radical" idea that space and time were a single entity: "Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality."



Fundació Gala-Salvador Dalí, Figueres, Catalonia, Spain © Salvador Dalí, Fundació Gala-Salvador Dalí, Artists Rights Society (ARS), New York 2013

Salvador Dalí: The Sense of Speed, 1931

So spacetime was born. In spacetime all events are baked together, a four-dimensional continuum. Past and future are no more privileged than left and right or up and down. The time dimension only looks special for the reason Wells mentioned: our consciousness is involved. We have a limited perspective. At any instant we see only a slice of the loaf, a puny three-dimensional cross-section of the whole. For the modern physicist, reality is the whole thing, past and future joined in a single history. The sensation of now is just that, a sensation, and different for everyone. Instead of one master clock, we have clocks in multitudes. And other paraphernalia, too: light cones and world lines and time-like curves and other methods for charting the paths of light and objects through this four-dimensional space. To say that the spacetime view of reality has empowered the physicists of the past century would be an understatement.

Philosophers like it, too. “I conclude that the problem of the reality and the determinateness of future events is now solved,” wrote Hilary Putnam in 1967.

Moreover, it is solved by physics and not by philosophy. We have learned that we live in a four-dimensional and not a three-dimensional world, and that space and time—or, better, space-like separations and time-like separations—are just two aspects of a single four-dimensional continuum....

“Indeed,” he added, “I do not believe that there are any longer any *philosophical* problems about Time.” Case closed.

Now comes a book from the theoretical physicist Lee Smolin aiming to convince us that time is real after all. He is frankly recanting the accepted doctrine—an apostate:

I used to believe in the essential unreality of time. Indeed, I went into physics because as an adolescent I yearned to exchange the time-bound, human world, which I saw as ugly and inhospitable, for a world of pure, timeless truth....

I no longer believe that time is unreal. In fact I have swung to the opposite view: Not only is time real, but nothing we know or experience gets closer to the heart of nature than the reality of time.

Smolin is a founder and faculty member of the Perimeter Institute for Theoretical Physics in Toronto, an authority on quantum gravity who has also written on elementary particle theory, cosmology, and the philosophy of science. He proposes to validate what we already know—those of us who wear wristwatches, cross the days off our calendars, mourn the past, pray for the future, feel in our bones the march of time or the flow of time. We unphilosophical naïfs, that is—known for short as the “man on the

street.” Hilary Putnam again: “I think that if we attempted to set out the ‘man on the street’s’ view of the nature of time, we would find that the main principle...might be stated somewhat as follows: (1) All (and only) things that exist *now* are real.” Past things were real once but have ceased to exist. Future things don’t yet exist; they will become real only when the time comes.

This is the view that most physicists deny and the view that Smolin proposes to demonstrate in his book. For him the past is gone; the future is open: “The fact that it is always some moment in our perception, and that we experience that moment as one of a flow of moments, is not an illusion.” Timelessness, eternity, the four-dimensional space-time loaf—*these* are the illusions.

His argument from science and history is as provocative, original, and unsettling as any I’ve read in years. It turns upside-down the now standard view of Wells, Minkowski, and Einstein. It contravenes our intellectual inheritance from Newton and, for that matter, Plato, and it will ring false to many of Smolin’s contemporaries in theoretical physics.

We say that time *passes*, time *goes by*, and time *flows*. Those are metaphors. We also think of time as a medium in which we exist. If time is like a river, are we standing on the bank watching, or are we bobbing along? It might be better merely to say that things happen, things change, and *time* is our name for the reference frame in which we organize our sense that one thing comes before another.

That most authoritative of machines, the clock, has no purpose but to measure something, and that thing is time. In fact you can define time that way: time is what clocks measure. Unfortunately that’s a circular definition, if clocks are what measure time. (Smolin suggests, “For our purposes, a clock is any device that reads out a sequence of increasing numbers,” which is interesting, even if it isn’t in the dictionary.) Scientists devote considerable resources to quantifying time, going beyond our usual seconds and minutes. Humanity has a collective official time scale, established by a chorus of atomic clocks cooled to near absolute zero in vaults at the United States Naval Observatory in Washington, the Bureau International des Poids et Mesures near Paris, and elsewhere. Isaac Newton would be pleased. International Atomic Time appears to codify the notion of absolute time that he worked so effectively to establish. Newton’s view, handed down to us as if engraved on tablets of stone, was this:

Absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly....

The cosmic clock ticks invisibly and inexorably, everywhere the same. Absolute time is God's time. This was Newton's credo. He had no evidence for it, and his clocks were primitive compared to ours. He wrote:

It may be that there is no such thing as an equable motion, whereby time may be accurately measured. All motions may be accelerated and retarded, but the flowing of absolute time is not liable to any change.

He needed absolute time, as he needed absolute space, in order to define his terms and express his laws. Motion is nothing but the change in place over *time*; acceleration is the change in velocity over time. With a backdrop of absolute, true, and mathematical time, Newton could build an entire cosmology, a "System of the World."

So Newton made time more real—reified it, as no one had done before. But he also made time into a useful abstraction, and in this way it began to fade away. When a scientist records a series of observations—the position of the moon, let's say—the result is a table of numbers representing both space and time. A generation before Newton, René Descartes showed how to turn such tables into graphs, using different axes for different variables. Representing the orbit of the moon in Cartesian coordinates makes it a curve in space and time—the whole orbit becomes static, a mathematical object in a timeless configuration space. On such a graph time is frozen, and the history of a dynamical system is revealed for study at leisure.

The technique has had psychological side effects, Smolin suggests. It gives those who use it the idea that the experience of time passing is an illusion:

The method of freezing time has worked so well that most physicists are unaware that a trick has been played on their understanding of nature. This trick was a big step in the expulsion of time from the description of nature, because it invites us to wonder about the correlation between the real and the mathematical, the time-bound and the timeless.

This is his crucial dichotomy: the time-bound versus the timeless. Thinking "in time"—i.e., time-bound—versus thinking "outside of time." We have inherited the idea of *timeless* truths from Plato: truths that exist in an ideal plane, in eternity. A leaf fades from green to brown, but greenness and brownness are immutable. Here in the sublunary world everything is subject to change and nothing is perfect; no actual triangle we experience is ever exactly equilateral. But in the mathematical world the angles of every triangle add up to 180 degrees. It was always so, and it always will be: mathematical truth exists outside of time.

In that same spirit Newton's laws, the laws of nature, are meant to be timeless, true now and forever. Otherwise what good are they? We can hardly value the ephemeral. "We yearn for 'eternal love,'" says Smolin. "Whatever we most admire and look up to—God, the truths of mathematics, the laws of nature—is endowed with an existence that transcends time." This leads to cognitive dissonance. We live in one world while imagining the existence of another, outside: a heavenly plane. Smolin argues that the belief in *timeless* truths is not only misguided but harmful. He writes that "we act inside time but judge our actions by timeless standards"—not only of laws such as Newton's, but also the precepts of religion or morality:

As a result of this paradox, we live in a state of alienation from what we most value.... In science, experiments and their analysis are time-bound, as are all our observations of nature, yet we imagine that we uncover evidence for timeless natural laws.

There is an alternative. We reenter time when we accept uncertainty; when we embrace the possibility of surprise; when we question the bindings of tradition and look for novel solutions to novel problems. The prototype for thinking "in time," Smolin argues, is Darwinian evolution. Natural processes lead to genuinely new organisms, new structures, new complexity, and—here he departs from the thinking of most scientists—new laws of nature. All is subject to change. "Laws are not timeless," he says. "Like everything else, they are features of the present, and they can evolve over time."

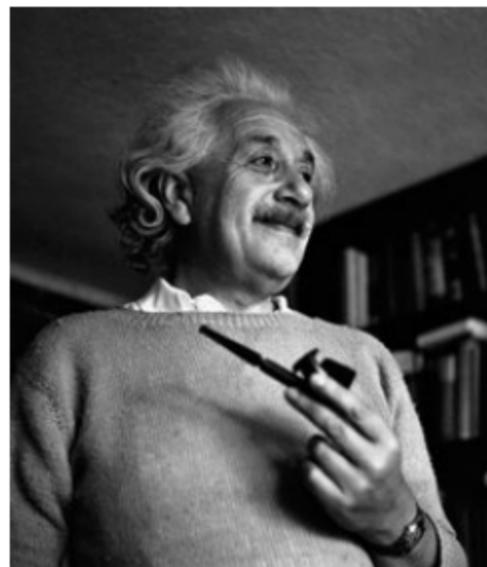
The faith in timeless, universal laws of nature is part of the great appeal of the scientific enterprise. It is a vision of transcendence akin to the belief in eternity that draws people to religion. This view of science claims that the explanations for our world lie in a different place altogether, the world of shadows, or heaven: "another, more perfect world standing apart from everything that we perceive." But for Smolin this is a dodge, no better than theology or mysticism. Instead, he wants us to consider the possibility that timeless laws of nature are no more real than perfect equilateral triangles. They exist, but only in our minds.

Smolin's argument develops slowly and builds suspense. The reader starts to wonder whether the lady being sawed into pieces will come out of the box alive.

The cosmic clock of Newton (or God), marking time absolutely, everywhere the same, did not survive. Einstein shattered it. He did this by refusing to take it for granted and asking a simple question: Is it possible to say that two distant events occur at the same time? Is that even meaningful? Suppose you assert that lightning has struck a railway embankment at points A and B, distant from each other, and that the lightning flashes

were simultaneous. Can you—a physicist with the most excellent equipment—establish that for sure?

You cannot. It turns out that a physicist riding on the train will disagree with a physicist standing at the station. Every observer has a reference frame, and each reference frame includes its own clock. Simultaneity is not meaningful. *Now* is relative. As Smolin puts it, “the clocks can be funky—that is, they can run at different rates in different places, and each can speed up and slow down.” We don’t have to like that. Every experiment confirms it.



Lucien Aigner/Corbis

Albert Einstein in his study, Princeton, New Jersey, 1940

Put another way, events in our universe can be connected, such that one is the cause of the other; or they can be close enough in time and far enough apart that they cannot be connected and no one can even say which came first. The distinction between past and future begins to decay. No observer has access to the *now* of any other observer. Everything that reaches our senses comes from the past.

Thus space and time are wedded. One cannot be measured—cannot be defined, can barely be talked about—independent of the other. Spacetime, having begun as a convenient technique of visualization, becomes indispensable. Time is frozen into the four-dimensional block. Motion gives way to geometry.

H.G. Wells said the only difference between time and space is that “our consciousness moves along it,” and likewise a half-century later the mathematician, physicist, and philosopher Hermann Weyl explained that the universe doesn’t “happen”—it “simply is”:

Only to the gaze of my consciousness, crawling upward along the world line of my body, does a section of the world come to life as a fleeting image in space which continuously changes in time.

Three weeks before his death, in 1955, Einstein wrote, “People like us, who believe in physics, know that the distinction between past, present, and future is only a stubbornly persistent illusion.” Yet Einstein was not altogether sanguine. He could not explain away our sense of time passing, our awareness of the present moment. “The problem of the Now worried him seriously,” recalled Rudolf Carnap.

He explained that the experience of the Now means something special for man, something essentially different from the past and the future, but that this important difference does not and cannot occur within physics.

Carnap, a philosopher of the Vienna Circle, suggesting leaving this sort of problem to the psychologists. Not Smolin: he thinks we should embrace Einstein's discontent:

Everything we experience, every thought, impression, action, intention, is part of a moment. The world is presented to us as a series of moments. We have no choice about this. No choice about which moment we inhabit now, no choice about whether to go forward or back in time. No choice to jump ahead. No choice about the rate of flow of the moments. In this way, time is completely unlike space. One might object by saying that all events also take place in a particular location. But we have a choice about where we move in space. This is not a small distinction; it shapes the whole of our experience.

Still, he knows that intuition is not an argument. For most of history, human experience made it clear that *up* and *down* are special directions, everywhere the same—*down* being where things fall and *up* being the home of sun and stars—and that did turn out to be an illusion. If you are in outer space, there is no up or down—those concepts are meaningful only relative to the surface of the earth or some other planet. Our senses tell us all sorts of lies.

In an empty universe, would time exist?

No, it would not. Time is the measure of change; if nothing changes, time has no meaning.

Would space exist, in the absence of any matter or energy? Newton would have said yes: space would be empty.

For Smolin, the key to salvaging time turns out to be eliminating space. Whereas time is a fundamental property of nature, space, he believes, is an *emergent* property. It is like temperature: apparent, measurable, but actually a consequence of something deeper and invisible—in the case of temperature, the microscopic motion of ensembles of molecules. Temperature is an average of their energy. It is always an approximation, and therefore, in a way, an illusion. So it is with space for Smolin: “Space, at the quantum-mechanical level, is not fundamental at all but emergent from a deeper order”—an order, as we will see, of connections, relationships. He also believes that quantum mechanics itself, with all its puzzles and paradoxes (“cats that are both alive and dead, an infinitude

of simultaneously existing universes”), will turn out to be an approximation of a deeper theory.

For space, the deeper reality is a network of relationships. Things are *related* to other things; they are connected, and it is the relationships that define space rather than the other way around. This is a venerable notion: Smolin traces the idea of a relational world back to Newton’s great rival, Gottfried Wilhelm Leibniz: “Space is nothing else, but That *Order* or *Relation*; and is nothing at all without Bodies, but the Possibility of placing them.” Nothing useful came of that, while Newton’s contrary view—that space exists independently of the objects it contains—made a revolution in the ability of science to predict and control the world. But the relational theory has some enduring appeal; some scientists and philosophers such as Smolin have been trying to revive it.

Nowadays, the Internet—like the telegraph a century before—is commonly said to “annihilate” space. It does this by making neighbors of the most distant nodes in a network that transcends physical dimension. Instead of six degrees of separation, we have billions of degrees of connectedness. As Smolin puts it:

We live in a world in which technology has trumped the limitations inherent in living in a low-dimensional space.... From a cell-phone perspective, we live in 2.5-billion-dimensional space, in which very nearly all our fellow humans are our nearest neighbors.

The Internet, of course, has done the same thing. The space separating us has been dissolved by a network of connections.

So maybe it’s easier now for us to see how things really are. This is what Smolin believes: that time is fundamental but space an illusion; “that the real relationships that form the world are a dynamical network”; and that the network itself, along with everything on it, can and must evolve over time.

We know that time runs one way, despite the apparent reversibility of most physical laws. The relational view supports the idea of the universe as a one-way street, growing ever more structured and complex in apparent contradiction to the second law of thermodynamics, which states that all isolated systems become more uniform over time. The second law has led physicists for more than a century to suggest that the fate of the universe is the cosmic equilibrium of “heat death,” a uniform state of maximum entropy and perfect disorder, but that’s not the universe we see. Instead it seems that the universe gets persistently more interesting. Smolin argues that the second law of thermodynamics applies to any isolated system within the universe but *not* to the universe taken as a

whole; that, in a universe where time is real and fundamental, it is natural for complexity to evolve and for systems to become more organized.

By declaring space to be secondary, he makes a mathematical trade that avoids contradicting general relativity: relative size for relative time. If size and location are relative, then time doesn't need to be. He arrives at a notion of "preferred global time" that extends throughout the universe and defines a boundary between past and future. It imagines a "family" of observers, spread throughout the universe, and a preferred state of rest, an abstract standard against which motion can be measured. Even if "now" need not be the same to different observers, it retains its meaning for the cosmos.

Time Reborn means to present a program for further study. Smolin maintains a fairly puritanical view of what science should and should not do. He doesn't like the current fashion in "multiverses"—other universes lurking in extra dimensions or branching off infinitely from our own. Science for him needs to be testable, and no one can falsify a hypothesis about a universe held to be inaccessible to ours. For that matter, *any* theory about the entire cosmos has a weakness. The success of science over the centuries has come in giving rules and language for describing finite, isolated systems. We can make copies of those; we can repeat experiments many times. But when we talk about the whole universe, we have just the one, and we can't make it start over. So Smolin sees little scope for science in the family of cosmic questions beginning with "Why...":

Why is there something rather than nothing? I can't imagine anything that would serve as an answer to this question, let alone an answer supported by evidence. Even religion fails here....

Better not to think of science as a quest for timeless truths. Science, he writes, creates "effective theories." These are models—incomplete by definition. They are effective in limited domains, and they are approximate. That doesn't have to be a failing. Science can construct better and better theories, approaching the truth with closer approximations. But a perfect model of the universe would have to be the size of the universe. We humans are finite creatures, with little brains.

It may seem that Smolin himself is taking on one of the grandest cosmic questions of all. He does try to restrain himself, though, to hypotheses that make testable, falsifiable predictions about the universe we can observe. The scientific case he makes is intricate, involving methods from loop quantum gravity (one of several approaches to combining quantum theory and the theory of relativity). He depicts the geometry of space as a graph with nodes and edges. He has reserved some detail for online appendices at www.timereborn.com and plans to publish a more rigorous formulation in

collaboration with the Brazilian philosopher Roberto Mangabeira Unger.

“The world remains, always, a bundle of processes evolving in time,” says Smolin.

Logic and mathematics capture aspects of nature, but never the whole of nature. There are aspects of the real universe that will never be representable in mathematics. One of them is that in the real world it is always some particular moment.

In a coda he ruminates briefly on the problem of consciousness—“the *really* hard problem.” He doesn’t propose any answers, but ■■ glad to see physicists, mathematicians, and computer scientists continuing to wrestle with it, rather than leaving it to neurologists. Whatever consciousness will turn out to be, it’s not a moving flashlight illuminating successive slices of the four-dimensional spacetime continuum. It is a dynamical system, occurring in time, evolving in time, able to absorb bits of information from the past and process them, able also to create anticipation for the future.

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