Lee Smolin. *Time Reborn: From the Crisis in Physics to the Future of the Universe*. Houghton Mifflin Harcourt, 2014. 352 pp. $15.95 USD (Paperback ISBN 9780544245594).

Lee Smolin is one of those physicists who has successfully bridged the gap between physics as a discipline that expresses its ongoing research in technical journals meant for fellow physicists and a general reading audience. His earlier text *The Trouble with Physics* (2006) is quite well-known. In *Time Reborn*, Smolin extends his intellectual reach further by delving into the meta-theoretical foundations of physics, through his research in the theory and philosophy of physics and science. A number of his views are iconoclastic which indeed makes his work interesting. The topic Smolin tackles in this text is that of time, a subject much explored by philosophers and theoretical physicists. Plato expressed the idea of an unchanging and true reality behind the changing world of sensibilia, and Kant in his *Critique of Pure Reason* (1787) argued that time is a 'pure form of sensuous intuition' which serves as an a priori pre-condition—along with space—for the sensory experience of phenomena. One might also note Henri Bergson's *Duration and Simultaneity* (1968, 7th ed.) that was critical of Einstein's interpretation of relativistic time, as per the well-known twin thought experiment.

In the text, Smolin attacks the view expressed in Platonic philosophy, Newtonian and Einsteinian physics, and quantum mechanics, that time is an illusion on account of the positing of constituent laws as universal and timeless, and thus not subject to change. Smolin's thesis is that time is indeed real, the laws of physics are not timeless, and they can indeed evolve over time. According to Smolin, the question concerning the meaning of time is fundamental to scientific inquiry concerning the mysteries physicists and cosmologists face. Smolin writes: 'What is time? This deceptively simple question is the single most important problem facing science as we probe more deeply into the fundamentals of the universe. All of the mysteries physicists and cosmologists face—from the Big Bang to the future of the universe, from the puzzles of quantum physics to the unification of the forces and particles—come down to the nature of time' (xi).

Smolin's thesis that all the major theoreticians of physics from Newton onwards argue that the structure of the universe, as expressed by the working laws of physics, assumes a timeless universe. In other words, time is assumed to be a nonexistent variable in the total structure of things. In the case of Newton this may seem odd, given that the laws of motion that are central to Newtonian mechanics operate on the basis of an existent time. Consider, for example, Newton's second law which relates force to mass and acceleration. The key variable here is acceleration which measures motion in time, which is velocity per second squared. Consider again the crucial role that time plays in Einstein's theories of relativity, as in the case of relativistic time according to the relative motions of bodies. A central principle of relativistic physics is the unchanging velocity of light, $187(10^3)$ miles per $sec.^2$. According to the speed at which objects are moving, time can be slowed down or speeded up. The well-known twin thought experiment illustrates this point. It is also a central element of astrophysics that the idea of measured time is crucial for understanding the structure of the universe. For example, distance between galaxies is measured in terms of 'light years' the evolution of entities such as stars is measured in time as they progress in time from the structure of 'star' to 'red dwarf'. So what then is the basis for Smolin's claim that the concept of 'timelessness' reigns in the theories of modern physics?

The idea behind Smolin's thesis is that the laws of physics are expressed in mathematical language which imbues them with an aura of timelessness. In pure mathematics, propositions

express the relations between ideas which are assumed to hold for all time. The same principle would necessarily apply to the laws of theoretical physics, given that they are intended to apply to the empirical world. This approach to the laws of physics was reinforced by the fact that theories founded on such laws proved to be empirically sound. This was the basis for the 'block universe' theory according to which the universe was a closed book with past, present and future all congealed in this universe as a block. Matters were reinforced with the Einsteinian idea of the 'relativity of simultaneity' according to which in special and general relativity, theory space and time are merged into a single structure of space-time.

So what is then that led Smolin to question and reject the orthodox theory concerning the 'timelessness of the laws of physics'? The answer is that the unidirectional nature of time in reality as opposed to its bidirectional flow according to the laws of physics impinges directly on human experience. The law of entropy (the second law of thermodynamics) testifies to this. The issue boils down to the matter of reconciling the fact that the laws of physics are equally valid in bidirectional time, yet the empirical reality is that events in time are unidirectional. Smolin opts for the latter fact as evidence that time is a real entity and is open-ended for the future. Leibniz's theory of the 'identity of indiscernibles' is also invoked in support of Smolin's thesis because 'our universe is one where every moment of time, and every place at every moment, is uniquely distinguishable from any other. No moment repeats. Looked at in enough detail, every event in the universe is unique' (215). In such a universe the laws of physics are not fixed for all time as in the Newtonian universe. This allows Smolin to argue for the evolution of the laws of physics.

I would think that there is incorrect terminology here. Laws that diverge from their original structures are no longer the same laws but new laws, which in turn reflect that the empirical conditions have changed. But is there anything really path-breaking about Smolin's thesis? The idea being that the structure of the universe in terms of its physical laws derives only from the fact that such laws are expressed in mathematical language which carries with it an aura of timelessness. For example, the basic laws of mathematics as a system of the 'relations of ideas' are assumed to be true for all time. Thus, when used to express real world phenomena, such as the flow of time, they imbue the phenomena themselves with the timeless nature of the employed mathematical expressions. But it should be understood that the process whereby abstract mathematical relations apply to existent phenomena does not necessarily promise an accurate fit. The correspondence between mathematical expression and reality is a purely contingent one. It is for this reason that the hypotheses and theories of theoretical physics must be eventually confirmed by empirical test. This indeed would debunk the idea that the laws of physics reflect a timeless universe.

In an aside, Smolin makes an interesting reference to the way modern neoclassical economic theory operates in a created universe of timelessness where human decision making is reduced to timeless laws of supply and demand reaching their stationary states at points of equilibria. It is on this basis that neoclassical economics as theory is seen as maximally incompatible with human behavioural choices in the real world. This situation is even more unreal than the situation in physics, where the laws are indeed required to cohere with reality. Smolin's idea that time is real leads him to argue that the laws of physics are not valid for all time but can evolve over time in the context of an open future.

But the real problem is the idea of time itself. We divide time into past, present and future. The past is recalled only through memory and we do not know the future. It is on this basis that probability estimates are of predictive importance in scientific analysis. All that humans experience

in this regard is the present, but is there an actual present? If the present is linked to the past through some experienced principle of causality then are there direct links between past, present and future? But this could mean that the future already exists but is unknown to humans. Does this mean ultimately that the 'block universe' hypothesis could indeed be sound? Smolin's critique is based on his acceptance of Leibnizian notion of the 'identity of indiscernibles' principle. But this principle is indeed compatible with the 'block universe' hypothesis. The discussion is not yet complete and must continue.

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