Clockwatcher

by Simon Saunders

Review of "The End of Time", by Julian Barbour: New York Times Book Review, March 26, 2000.

Like Stephen Hawking, Julian Barbour is a physicist who spends his time on time. Like "A Brief History of Time", this book is about time and about its history. It is about how time has been treated in various physical theories, leading up to the present. But unlike Hawking's study, Barbour's "The End of Time" is genuinely self-contained and really does explain its central ideas. It is a quest into the nature of time. Barbour is asking what time really is. His answer, in the light of all that we know of the physics, is that there is no such thing. Time does not exist. The answer sounds insane.

But Barbour is no madman. As an historian he speaks with authority: he has written a classic study of the history of theories of motion. And he is a physicist of note; he has himself earned a place in this history.

Of course we are used to physicists saying extraordinary things. Einstein, famously, denied that the distinction between the past and future is real. There is no doubt that the theory of relativity - Einstein's theory of gravity - put in place a "spatial" view of time. Time and space appear to become aspects of a single four-dimensional reality. But novel though it is, in one respect this conception is already familiar. It goes back to Parmenides of Elea and to the idea of reality as changeless and eternal: space-time as a whole does not change; change is represented by the relations of its parts. Philosophers today call this the "tenseless" view of time, but "spatial" would be more apt: according to it time, like space, is how events are related to one another. Time binds them together. Time is like space.

But Barbour is denying that time is like space. Events aren't situated in any fourth dimension, and nothing binds them together. In this sense time does not exist. But then how are we to think of change, and all of the things we ordinarily think of as happening in time?

For Barbour space is the primary reality. We must begin with the shapes of things, in all their spatial relations to one another. Imagine, if you will, collections of triangles and cubes, and other geometrical shapes. Think of an entire three-dimensional universe as built up of them, together with all their spatial relationships. Call this a *configuration* of the universe. One configuration can be compared to another, not with respect to their relation in time or space (for they are not "in" time or space), but qualitatively, in terms of their internal, intrinsic properties. Every configuration is unique, and each dictates its relation to every other. Welcome to *Platonia*, as Barbour calls it, the space of all qualitative shapes. This is the central concept of the book.

Platonia is a powerful idea, but to tease out its significance we need to know more about how Barbour arrived at it. A first step is to see how these ideas work in the most simple and fundamental case, Newton's theory of gravity. It was Barbour who, in 1982, with the Italian physicist Bruno Bertotti, first solved a problem that Newton had thought insurmountable, and that Einstein tried to address but failed: of how to treat rotation in relative terms. Rotation seems to be absolute, not relative. An object rotating relative to its surroundings feels a centrifugal force; if the surroundings are rotating about the object instead it does not. But this asymmetry is illusory, as Barbour and Bertotti showed. The key idea in fact goes back to Mach, the great Viennese physicist and philosopher; it is that the relational view applies only to the entire universe, to configurations, not to anything less. It was Ernst Mach, the very same, who played such an influential role in Einstein's thinking on relativity theory, but Einstein never did succeed in carry through Mach's program.

Solving the rotating body problem gives a new way of thinking about laws of motion. Normally one must first fix the initial conditions, the initial positions and speeds of all of the particles. Speed is about distance and time; time seems to be built in right from the beginning. The new way of thinking makes do with intrinsic differences; we only need a pair of configurations, without any further information on their putative relation in time. When they are very close together in Platonia we get in effect a direction. From a point and a direction in Platonia we can determine a unique path on which they lie. We obtain a sequence of configurations. We can think of this as a sequence of instantaneous states of the universe. We are getting something like history, something like time. But there was never any mention of time to begin with, nor do we have to interpret a path in Platonia in terms of time.

This idea is so good that it can be applied to Einstein's theory of gravity as well as to Newton's. Astonishingly, albeit with one or two caveats, one can recover the successful predictions of general relativity as well. This result is amazing. Revealed is the fundamental role of three-dimensional space in the one theory that is supposed to be fusing space and time into a single unity. This is what Barbour calls the "deep" structure of Einstein's theory; of it Einstein had not a clue.

These theories seem to be timeless, but it can be objected that they simply present time in an unfamiliar light. We are not yet finished, however. To prepare for the next phase, bear in mind that neither Newton's theory, nor Einstein's, are what is actually used when it comes to our knowledge of the past. With the exceptions of eclipses and the like, all that we know of history has a completely different source. What we actually know about the past comes almost entirely from *records* and *memories*. This, Barbour suggests, is the deeper, and more fundamental method for defining the past. Certain kinds of configurations contain within them copies of others. In a geologist's specimen there are shells, bones, and spores, the past in petrified form. As we descend to the microscopic level, the past is there all the more. Each point in Platonia is unimaginably, mind-numbingly vast - a possible way in which all the particles in the entire universe may be related to one another - and the history it encodes may be vast as well. Configurations like this Barbour calls *time capsules*. Most points in Platonia are not like this. Most of them are unstructured, either barren or inchoate. But our world is highly structured. A configuration of the earth, and of any living thing, is a time capsule *par excellence*. But if this is how we really know anything about time, in practice, then perhaps that is all there is to it. Really there are only time capsules. You and I, at this moment, are in a single configuration; we are inside of the instant. An instant is not in time, time is in the instant.

Finally we come to quantum mechanics. Other ideas that Barbour deals with have a long history, but nobody, at the turn of the century, expected quantum mechanics. No reasonable person, considering quantum mechanics, thinks it is reasonable. Einstein once said that God is subtle but not malicious; maybe he was wrong. There is no uncontroversial interpretation of quantum mechanics. There is no agreed theory of quantum gravity. Reconciling quantum mechanics with gravity is the fundamental problem of physics. Every attempt at it so far has failed.

Of the handful of approaches to quantum gravity the one

Barbour is concerned with is the oldest and the most straightforward. On this, the "canonical" approach, right from the start Einstein's theory is rewritten in terms of space and time. Quantum mechanics was arrived at by a certain mathematical procedure applied to Newtonian mechanics and the equations of electromagnetism; apply the same procedure here, amended where necessary. The result is a quantum theory of gravity. But no-one knows how to interpret the results. The equation one gets out makes no reference to time at all. Nor can anybody solve this equation; for all that we know it may not make any mathematical sense. As for the comparison with experiment, don't even think about it.

Barbour has nothing to say about the mathematical problems (but then every approach to quantum gravity has mathematical problems); but he can help with the interpretation. Difficulties arise because one has not appreciated the "deep" structure of Einstein's theory. The objection to the canonical method is likewise misplaced. It is objected that the beautiful four-dimensional symmetry of Einstein's theory should be preserved; in the the deep structure it is not of importance. It is supposed to be a difficulty that time does not appear in the quantum equation; but neither does it in Barbour's formulation of Einstein's theory. Barbour is offering us a perspective on quantum mechanics and relativity in which their concepts are already at one.

But there is more damage to time. The crucial point, going over to quantum gravity, is that we lose the mechanism for defining paths in Platonia. Because of the Heisenberg uncertainty principle, we cannot precisely define a point and a direction in Platonia together, no more than we can position and velocity in quantum mechanics. In quantum gravity, Barbour is saying, we cannot define sequences of points at all. The fundamental equation does not pick out any one point and it does not pick out any one sequence of points. Instead it picks out a collection that cannot be parceled up into sequences at all, not even into a plurality of them. The idea of a linear order of them has all but disappeared. And time goes with it: there is only a collection of points in Platonia, the ones singled out by solving the fundamental equation.

With that Barbour arrives at a version of the "many-worlds" interpretation of quantum mechanics. Multiple worlds have been quite popular in recent times, and not only, as with David Deutsch (in *The Fabric of Reality*), to make sense of quantum mechanics. Physicists like Martin Rees (*Just Six Numbers*) and Lee Smolin (*The Life of the Cosmos*) use them to explain why the universe seems so user-friendly; philosophers like David Lewis (*The Plurality of Worlds*) use them to account for our understanding of possibility. Barbour is using them to replace our idea of time. Time is a way of saying things are different without falling into contradiction. Without time we must put things in different worlds instead.

But how, if there is no time, if there are not even any sequences of instants, do we account for the fact that it seems that there is? The answer, in a word, is time-capsules. We are contained in a time-capsule. The points of Platonia selected by the equation of quantum gravity are precisely the time-capsules. The equation selects for complexity, structure, variety. There is evidence for this in atomic physics. There are models going back to the beginnings of quantum mechanics, where it was shown that the solutions pick out something very like time-capsules (models of particle trajectories in bubble chambers, for example). Barbour is here making the conjecture that something similar will apply in quantum gravity. He is in thrall to the dream of Gottfried Leibniz, the greatest of the philosophers and mathematicians of the early modern period; the fundamental law is to select the best of all possible worlds, meaning (as Leibniz meant it) the most richly varied possible. Leibniz's only error was to think that they could all be combined into a single sequence.

Now all this is very difficult to clearly grasp. For those who will try, and read what is in fact a wonderfully accessible book, I must dutifully issue a philosophical health warning: I do not know if it really makes sense. The difficulties range from manageable conceptual ones, for example of how a thought (which takes time) can be coded into an instant (which takes no time at all), to the intractable mathematical ones already mentioned. But there is one question that is left hanging that Barbour would have done better to answer directly. Can time capsules be put into nested sequences, at least in special cases? One time capsule contains relics of another, so in this sense is related to it; and so on to the next. Barbour has given us this much, and it is hard to see why we should not make use of it. If we can obtain sequences of this sort, if only in special circumstances, then our lives if only in a piece-wise sense can be supposed to be composed of them. With that we can make the same sort of sense of our ordinary experience of time as we can under the tenseless view. It is true that in consequence Barbour should not be saying that time does not exist, but rather that this is what time is; but any loss in the excitement of his claim would be more than compensated by an increase to its intelligibility.

There is much more to this book than I have been able to touch upon. Barbour leaves his mark on every topic he considers; the arrow of time and the origins of the Big Bang are further examples. One is left with a remarkable conception of reality. One is left with a sense of a personal quest, for Barbour tells us something about his life and how he came to these ideas. Above all one is left with a sense of what economy of thought can truly be, of how shocking and how sparse are the ideas that physics may really need. From beginning to end the book strips away concepts that are shown to be redundant. As pedagogy and as analysis it is a masterpiece.