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The Times are Many

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Einstein vs. Bergson

An Enduring Quarrel on Time

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Carlo Rovelli

Preface: The Times Are Many

I have had the misfortune, but also the fortune, of not being able to participate in the conference that has prompted the publication of this book. It was a misfortune because I missed the livelihood of the presentations and especially the personal discussions, debates, and quarrels that are the true life of conferences. But it was also a fortune, because I received this entire book, and could read it all, calmly, and meditate it, before writing this Preface. So, this Preface is really a *a-posteriori* reflection on the content of the book.

I believe that the debate on the nature of time is based on a substantial mistake. The mistake is to assume that there is a single something, which is *Time,* whose nature we somehow have to grasp. This, I think, is the origin of all the confusion. Time is a very concrete reality we experience directly (we are late, we enjoy time, we die). It is essential in our life. But it is not a single notion; it is a stratified notion, generated by a variety of different phenomena, and we are confused when we fail to disentangle them.

When Bergson talks about Time, he knows what he is talking about. It is the time we experience. The experience of the passing of time is a real and concrete experience. I find that to call this passing of time *illusory* is misleading: there is nothing illusory in the passing of time: on the contrary, it is one of the most solid and objective realities we face.

But to identify this experience with the physics of the ticking of a clock and the motion of a pendulum is a mistake. The two phenomena (our experience and the ticking of the clock) are related, but they are not the same phenomenon. To say that they are the same is like saying that a novel written on the numbered pages of a book is the same thing as the sequence of the numbers of the pages. Our experience of time is a rich experience that is powerfully coloured by things like the memory we have of past events (and not of future events, I'll come back on that), the constant anticipation of the future that our brain is concerned with, and the intrinsic motivations of our activities that are constantly driven by motives and that therefore orient us towards the future (Husserl has described this phenomenology with great insight). Our experiential time is made of all this. Clocks do not have memories, do not anticipate the future, do not calculate what they have to do next and do not have objectives. Hence clocks do not have the experience of time that we have. The time of the clock (is related to but) is not the same thing as the time of our experience. The time of elementary mechanics is (roughly) the time of the clock. It misses entirely the time of our experience.

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Does this mean that the time of our experience necessarily escapes scientific inquiry? No, why should it? Simply, it requires us to study a more complicated system than a pendulum or an elementary clock. Concretely it requires us to make two distinct steps, both important.

The first step is to distinguish the complete description of natural systems that is assumed in mechanics from the strongly coarse-grained description of natural systems that is studied by thermodynamics and statistical mechanics. In particular situations (such as in our universe, or at least the portion of the universe where we happen to inhabit), the variation in (clock) time of certain coarse-grained variables (such as those through which we interact with the world around us) is strongly oriented: it satisfies the second law of thermodynamics. One can show that in such situations the macroscopic variables rather generically present traces of the past but not of the future (Rovelli 2020a), and the macroscopic evolution can branch towards the future but not towards the past (Rovelli 2020c). Therefore, in a precise sense the past is fixed and the future is open: meaning that the macroscopic present state has large information about the macroscopic state of the past and much less about the future. These are facts of the natural world.

These observations explain why the physical phenomenology we observe is so strongly oriented in time, but they are not sufficient to account for the time of our experience: the time of thermodynamics is closer to the time of our experience than the time of mechanics, but it is not yet it. To account for the time of our experience we have to take into account the specific functioning of our brain: its peculiar way of dealing with memories, anticipations, and aims. The science that deals with that is neuroscience, not physics.

Does this mean that the time of our experience is somehow in contradiction with physics? Of course not! That would be like saying that an airplane is in contradiction with physics, because we study it in specific aero-space books and not in elementary books of mechanics, or a computer is in contradiction with physics because informatics is not physics. There is no contradiction between the behaviour of complex systems studied by branches of sciences and elementary physics. There may be articulations that we do not control well, phenomena that we have not understood yet, but we haven't any evidence of contradictions.

Now comes the key point. The mistake is to take the complex experience of time that we have and to assume that all aspects of it are general, and must underpin nature in general. This is a serious mistake, and is the first mistake that Bergson makes. This is a very common mistake. Let's look at it more in detail, because it is the central source of confusion in the debate about time.

Let me make a simple example that I find illuminating. Consider the notion of *up* and *down*. This is a very useful notion. It is obviously not illusory. It is real.

It is very intuitive for us. It is even a bit hard to avoid it in thinking about space. Does this imply that everywhere in the universe there must be a *up* and a *down* well defined as they are around us here? Of course not. *Up* and *down* are notions that make sense in the vicinity of the surface of a big mass (the Earth for us), not in an arbitrary point of interstellar space, where all directions are the same. So: *up* and *down* are useful notions to organise natural phenomena in our immediate environment, but we make a mistake if we illegitimately extrapolate their relevance. They do not have global relevance. The example shows that some notions that we consider intuitive are good but are not applicable to domains larger than those in which our experience developed.

Let's use this observation in relation to the notion of time. As we have seen, some aspects of our experience of time depend on our specific functioning (our brain). Others of course do not. For instance, all temporal characteristics of a clock as they are described in Newtonian mechanics do not depend on our brain. The aspects of time that differentiate the time our experience from the time of elementary physics, namely precisely those on which Bergson focused, depends specifically on our brain.

The fact that some macroscopic phenomena depend also on us should not be a surprise. Think at the sunrise, sunset, and the entire rotation of the sky. It is not a phenomenon concerning the Sun and the sky alone: it is a phenomenon that involves both the position of the celestial bodies and our own position on a spinning planet. There are many aspects of the phenomenology that we observe that have this double nature (colour is another typical example). The time ticketed by a clock has nothing to do with the functioning of our brain, but the time we experience does. Projecting the features of experiential time outside ourselves is like pretending to understand why colour space is three dimensional without taking into account that our eyes have receptors sensitive to three difference frequencies: a silly objective. This is Bergson's mistake. Time is not a single notion: we must disentangle its features to understand it.

But this is only half of the story, because the Bergson-Einstein debate was prompted by Special Relativity. The point made above, in fact, becomes much stronger with modern physics. Let's see how.

What Einstein realised first is that the common idea that the duration between two events is a fixed quantity is only a first approximation due to our limited experience. Two clocks that are separated and moved back together in general have measured different time intervals. Two persons separated and then brought back together in general have aged differently. This is a hard fact, pace Bergson, who denied its possibility. A fact that today is supported by innumerable concrete experiences and is virtually out of doubt.

This hard fact implies that our intuition of a common global time does not represent nature correctly. Is not that our intuition is wrong. It is right, but it refers to the domain of experience that is familiar to us with the precision in evaluating time durations that is familiar to us. What is wrong is not the idea that we all age together (here on Earth, and as far as we usually see, we do): what is wrong is to extrapolate this idea to situations of which we do not have much experience.

There is never a contradiction between the *manifest* image of the world, and the scientific one, if we are careful in not extrapolating. The *manifest* image is how things correctly appear, within our approximations and precisions. The difference between the *manifest* image of the world and the scientific one is the same difference as the image of a forest on a mountain seen from afar as a uniform green velvet, and the image of the same forest as a complicated mess of trees, as seen from nearby. There is no contradiction between the two images: they are just how something looks from two perspectives.

The Newtonian idea of a universal common time, thus, is simply wrong. Contrary to what some time stated, by the way, cosmology does not rescue it: the *cosmological time* is only an average, good only in the homogeneous approximations. The *proper time since the Big Bang* measured on Earth is different from the time form the Big Bang measured on Andromeda (or even on Jupiter for that matter), because proper time runs at different speeds depending on the masses nearby (a hard fact). When Andromeda and the Milk will meet (they are going to), what will be the age of the universe? That measured in Andromeda or that measured in the Milky way? The answer is that the 'age of the universe' is an approximate notion only. It breaks down in the details.

It follows that the notion of a common present all over the universe makes no sense, given what we know about the world. Hence Presentism – in the sense of the doctrine that reality is just what exists in the present all over the universe – is in flagrant contradiction with what we actually know about Nature.

Contrary to what often claimed, however, this does not force us towards the absurd metaphor of a static four-dimensional 'block' universe, where nothing moves (Rovelli 2020b). The fact that temporality is organised differently from what we thought does not imply that there is no change, no happening, in the universe. (To be static is not to change in time: in which time would the block universe be 'static'?) If anything, the opposite is true: the 4-dimensional spacetime of General Relativity is not static in any sense, and is not 'block' in any sense: it is the description of happenings. It is the description of stories, events, changes. These just do not happen to be organised along a single temporal sequence: given two of them, sometimes there is no meaning in asking which happened first. They are organised in a complicated 4-dimensional geometry that

Einstein's theory describes. What Einstein's theory describes is not a static reality: it is the real agitated universe we see moving around us, the way different happenings influence or do not influence one another.

Of course, it takes an effort of imagination to understand clearly a four-dimensional ensemble of events (happening) that does not flow in a single sequence. But this is the same kind of effort of imagination that at first makes it hard to believe that the Earth is round and people elsewhere live upside down with respect to us; or that we are standing on a fast-spinning rock. It always takes an effort of imagination to realise that Nature is not everywhere organised according to some conceptual prejudice we developed in the limited domain we habit. But we humans have a good adaptable brain: we learn, and we are capable of coming out from prejudices. A relativist who works with General Relativity gets used to it and then considers it so natural that she has difficulty remembering why for most of us it is natural that all clocks tick at the same speed.

To adapt our intuition to our discoveries, however, we must avoid a common methodological mistake: to confuse introspection with investigation of general aspects of nature. This is the mistake of some philosophy (certainly not all philosophy). Understanding with precision and investigating our own concepts and our own intuitions is great, but only if we are open to the fact that these same concepts and intuitions may *not* be appropriate to describe the world at large. This is again Bergson's mistake: confusing the phenomenology of human experience of time with necessary aspects of nature.

You see that Bergson's mistake is therefore double. First, he misunderstands the relation between experiential time and Newtonian time, and attributes the (real) discrepancy between the two to a presumed incompleteness of the scientific description of the world. Instead, it is just the result of the fact that the human brain is complicated. This is the same mistake as saying that fundamental physics is necessarily intrinsically incomplete because in the world there are bicycles and elementary physics books to not contemplate bicycles.

The second mistake is to resist Einstein's discovery on the basis of the fact that they contradict his intuition. Of course, they do: so does the fact that the Earth is round and spins. Our intuitions must adapt to new knowledge, not vice-versa.

So far, I have only talked about physics that is well established. Let me close by talking about the problem of time in Quantum Gravity, because this is the domain in which I work, and there are numerous discussions about Quantum Gravity in this book.

I think, again, that most discussions about the problem of time in Quantum Gravity are mistaken and misleading. In fact, I do not see any problem of time in Quantum Gravity. The problem appears only if we pretend to project onto the

physics of quantum gravitational phenomena a notion of time that does not pertain to it, that is not appropriate to describe it.

Quantum Gravity is a theory of events, of happenings. In this sense it is 'temporal'. But these events are not organised in a single sequence labelled by a single preferred time parameter, nor organised in a 4-dimensional continuum theory as in Einstein's geometries. They are related to one another probabilistically and the theory provides the probability relations of some events given others (Rovelli and Vidotto 2014). All this can be done without any need of a specific 'time' variable. The world is described by variables, and by the probability amplitudes describing the relations between them. Relativistic physics is not the description of how physical variables change in time: it is the description of how physical variables change with respect to one another (Rovelli 2004). This is coherent, and the question 'where is the time variable' is a meaningless question (Rovelli 2011), like the question 'where is the centre of the universe?' As far as we know a universe has no centre. To search for a time variable for Quantum Gravity is like searching for the centre of the universe: it is to project a notion that pertains to a limited domain onto a physics where this notion does not fit.

The variables that describe the gravitational field are among the variables in the theory. They have a property: in the classical approximation in which we disregard quantum phenomena they happen to admit an interpretation as a 4d space-time Einstein geometry (Rovelli 2020d).

In the further approximation when the gravitational field is weak, this geometry is approximated by Special Relativity. In the further approximation where things move at small relative speed, there is one special variable of the gravitation field that is precisely the Newtonian time variable, and our clocks track it.

In the further approximation in which we limit ourselves to macroscopic variables, our universe is time oriented, has traces of the past and is open towards the future. If we then consider also the specific functioning of the human brain, which is immersed in the time oriented macroscopic thermodynamic world, and we fold in its memories, its anticipation of the future and the motivations and aims that are intrinsic to its functioning, we get the full phenomenology of experiential time.

So, the solution to the problem of the nature of time is to break the problem apart into pieces. To understand all aspects of time we have to use all these different scientific theories. There is no single 'true' time: there are the events of Quantum Gravity, there is the space-time of General Relativity with its notions of multiple proper times along different paths, there are the different Lorentz times of Special Relativity, there is Newtonian time, there is the oriented time of thermodynamics, and there is the experiential time experienced by us, which are our brains and bodies. None of these 'times' (plural) is the 'true'

time. They are all related, but all different, because they are distinct by different properties (Rovelli 2018).

Quantum gravitational events, *general relativistic proper time*, *Lorentz times*, *Newtonian time*, the *oriented time of the second law of thermodynamics*, *experiential time* (or, better, *the different times of our experience*), these are all related but distinct times, and the confusion comes from confusing them or pretending that the feature of the more complex notions must apply to more general domains than what is proper to them.

So, in a sense, it seems to me that many of the articles in this book are right, but they talk about different things, pretending to be all talking about the same thing. The mistake is only if they pretend to capture a *true general nature* of time. If they do so, they sound to me like the blind men describing the elephant after having touched different parts of his body: 'it is a column!', 'no, it is a tube!' ...

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