There is no Arrow of Time

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Abstract
Instead of the linear temporal description of reality, I illustrate an alternative model which eradicates the concepts of direction and entropy from that of time. Time, intended as a Relationist measure of change, has only the possibility to pass positively or to stay still: the unidimensional mathematical metaphor is misleading, it is not possible to live or experience reality backwards. In light of that, I provide a different reading of the time-reversal invariance of the fundamental laws of physics.

Aim and structure of the paper
In the first paragraph, I claim that the time reversal invariance of local or macroscopic descriptions of physical systems should not be interpreted in a strong ontological sense – we should pay attention to get the right moral from the mathematical translation of a physical situation. In the second, I show the difficulties that emerge when we try to tie together entropy and time: besides the problem of making sense of the expression "entropy of the universe", many convincing thought-experiments could be generated to show how entropy and time are not related. In the third, I maintain that the Second Law of thermodynamics simply states a statistical truth – it doesn't impose a direction on nature. In the fourth and final paragraph, I sketch a Relationist temporal account. Without change (if everything freezes at 0 Kelvin, for example) there is no passage of time. There is no need of an arrow of time, because there are not two different directions, the only possibilities are to change or not to change. Finally, I defend the view from possible charges of circularity, and indicate some possible further developments.

1. The *time-reversal invariance* of the fundamental laws of physics
A very reasonable way to conduct an ontological analysis of our universe is to look at the best scientific theories available, with the goal of determining what they imply about reality. What is not always clear, though, at a time in which mathematics and physics have developed their own language, their

own practice, is how and to what extent it is possible to translate physical-mathematical models into a definite description of reality. Fundamental science has mainly to do with concepts and structures that are well defined under a mathematical point of view, but undergo some difficulties when it comes to represent those contents intuitively (in the world out there).

A possible reaction consists, of course, in attributing every sort of problem to our intuition. Since we don't experience the fundamental physical reality, the reasoning goes, it is obvious to find its concepts and descriptions exotic. A different possibility, however, is to argue that mathematics and physics have not only their own language, but also their own rules, part – in a certain sense – of their own world. Many times the translation from one world to the other is simple, even obvious, some other times, though, it is not. A classical example is the notion of line – what does it mean that a line has an infinity of points? This has a definite mathematical meaning, but what about its physical meaning?[1] The current scientific formalization of many basic entities (universe, time, space, …) contain a great number of internal rules that are not directly translatable into the physical world that surrounds us. The problem of the so-called arrow of time, I believe, has something to do with it.

The usual approach, when we speak about the problem of the arrow, starts off by acknowledging that the fundamental physical laws are time-reversal invariant (it seems that micro-physics recognizes no directionality of time). Anything that happens could, under a microphysical point of view, happen in reverse. Our experience, on the other hand, seems to tell a very different story. The cause-effect relation is always well aligned past-to-future, and the idea of effects occurring before their causes is absurd to many of us. Experience sees an asymmetry where fundamental physics sees none.

David Hume observed[2] that causal relations could be symmetric, what we call causes could just be events that we constantly see before what we call effects. Huw Price (1996) makes an analogous point: his conventionalist approach ("a version less arbitrary then Hume's"[3]) does not recognize any intrinsic temporal direction, and refuses to see causation as providing one. In rejecting the so-called Humean view that the asymmetry of the causal relation

1 Zeno's paradoxes where based on this: the present solution to the famous "Achilles and the Tortoise" argument (thanks to the concept of limit), after all, is not a real solution; Zeno could always insist that this is just a stipulation.

2 I am aware that there are many readings of Hume's philosophy. I am here accepting Price's interpretation.

3 Price (1996), p.137.

is merely a conventional image of earlier-later ordering, philosophers have noted that outgoing processes from a common center tend to be correlated with one another, whereas incoming processes meeting at a common center always seem to be uncorrelated (think of a video of a stone thrown in a pond, played normally and then backwards). That's why our experience strongly suggests that there is more behind this than just a temporal ordering convention – a fork asymmetry (four effects of one common cause). But the fundamental laws of physics seem to tell a different story. Consider Price (1996):

> to the extent to which there is a statistical asymmetry of this kind in the world, it is a macroscopic affair, depending on the coordinated behavior of huge numbers of microscopic components. But […] the component processes themselves seem to be symmetric in the relevant respects; there seems to be no fork asymmetry in microphysics.[4]

This fork asymmetry that we experience in the world seems to disappear when we focus on the microstructure of the physical processes in which it shows up, just as the pictorial content of an image disappears when we focus on the individual pixels that constitute it.

Imagine[5] a young man smoking a cigarette. If we see this process in the usual temporal direction, clouds of smoke come out of his mouth and disperse in the air. The reverse of this macroscopic process is, simply, absurd; but if we had a powerful zoom and saw the process at a molecular level, the situation would be radically different. A video of some molecules moving would make sense played forwards *and* backwards. It seems, the reasoning goes, that asymmetry emerges only at a macroscopic level. After all, Price argues, if we think of the history of our universe in reverse, what we would see is a collapsing universe and entropy decreasing: “there is no objective sense in which this reverse way of viewing the universe is any less valid than the usual way of viewing it. Nothing in physics tells us that there is a wrong or a right way to choose the orientation of the temporal coordinates”[6]. What Price has in mind is that a certain sequence of events (man lighting a cigarette, smoking it, tossing the butt) is happening in a certain temporal direction (past to future), which is not the only possible one.

4 Price (1996), pp. 140–141.
5 See Braibant, Giacomelli & Spurio (2009), p. 137.
6 Price (1996), p. 84.

2. Entropy and time

Within the philosophical community there is the widespread idea that the direction of time is nothing but the direction in which entropy increases. It seems, in fact, that the Second Law of Thermodynamics is the only law in physics that shows a temporal orientation. Thus, it is often considered the only candidate to physically ground the temporal orientation of our experience. Since physics, as Tim Maudlin puts it, does not distinguish at the level of fundamental laws the future direction from the past direction, "any such distinction must be grounded in contingent facts about how matter is distributed through spacetime […]. The direction of time, we are told, is nothing but the direction in which entropy increases"[7].

As I see it, there are three different possibilities here. We could claim that time is going forward *because* entropy is increasing, that entropy is increasing *because* time is going forward, or that time is going forward *and* entropy is increasing (without any causal or necessary relation between the two). The first scenario is the most accepted, because there is a physical law grounding the direction of time. The second option is preferred by philosophers with a more metaphysical taste. Their task, in turn, is to explain what grounds the thermodynamic arrow (causation, a substantivalist conception of time, etc.). The third possibility is a sort of conventionalist idea. Consider these words by Ludwig Boltzmann[8]:

> for the universe, the two directions of time are indistinguishable, just as in space there is no up or down. However, just as at a particular place on the earth's surface we call 'down' the direction toward the center of the earth, so will a living being in a particular time interval of such a single world distinguish the direction of time toward the less probable state from the opposite direction (the former toward the past, the latter toward the future).[9]

Since we constantly observe entropy increasing, we say that more events correspond to more disorder, and we call this increase of disorder *future*. This, however, is just a result of the particular point in space or time that we occupy. The Second Law of Thermodynamics, then, is not the source of the

7 Maudlin (2007), p. 17.

8 The words by the Austrian physicist serve just as an introduction to this third position: I am not maintaining that this was his view (and it probably wasn't, even if he tended to change his mind).

9 Boltzmann (1964), pp. 446–447.

temporal asymmetry, simply because there isn't any direction, any asymmetry. There is no time in a strong, Newtonian, substantivalist sense, there are only things happening in temporal relations. We are, by chance, in a particular situation in which we observe the universal entropy constantly increasing, and we call it going towards the future, but what we really mean is going towards an entropy increase. Even this Relationist version, however, share with the former two options a deep flaw: it is absolutely not clear what "entropy of the universe" means.

As popularly understood, the Second Law implies that a physical property, entropy, increases monotonically with time. Entropy, however, is definable only for systems in thermodynamic equilibrium, and the universe is *not* in thermodynamic equilibrium. Many philosophers and scientists[10], then, argue that the notion "entropy of the universe" is simply nonsense, and that the thermodynamic concept of entropy can only be defined for particular physical systems under special conditions. Thermodynamics makes sense when we focus on small thermally isolated bodies, whose volume and shape could be altered adiabatically by outside intervention. The concept of entropy itself could be understood only for systems in equilibrium, a state that cannot be ascribed to the universe as a whole. Thus, it is not clear how it is possible to ground the temporal asymmetry we see in the world on the inappropriate global extension of a local concept. This is sufficient, claims Roberto Torretti, "to dismiss the popular understanding of the second law of thermodynamics as a law of cosmic evolution, [and] to disqualify thermodynamic entropy as the physical source of universal time order"[11]; Clausius' cosmic version of the law, therefore, not only lacks any type of empirical warrant, but "clearly demands a much greater exertion of the human fancy than it is reasonable to allow in science"[12].

Obviously, we can concede that, even if it is not physically correct, it is at least intuitively possible to think of the universe as a giant box containing particles – but it is just a rough idea. The forces that are relevant at a cosmological level are completely different from the forces that are relevant for molecules in a box. Even Peter Evans, Sean Gryb and Karim Thebault, who consider – with Price – the idea of grounding our temporal experience on the entropy gradient very appealing, admit that

10 See for example Callender (2001) for a comprehensive review of the positions.
11 Torretti (2006), p. 740.
12 Torretti (2006), p. 753.

> the precise nature of the connection between the thermodynamic asymmetry and our asymmetric epistemic relationship to the past and future is a matter that remains largely unexamined […]; it is particularly problematic for the case of quantum cosmology where an explanation in terms of local thermodynamic arrow of time is inadequate. The fact that the universe is clearly not in thermodynamic equilibrium means that it is not possible to employ a thermodynamic notion of entropy in the cosmological setting.[13]

Moreover, even conceding, for the argument's sake, that the notion of universal entropy had a meaning, how should the increase of entropy determine effects to happen after causes? Imagine a box divided in two identical halves by a partition. In the left part there are ten red molecules, in the right part there are ten blue molecules, and the box is in thermodynamic equilibrium. If we remove the partition, the entropy of the system will increase (entropy could be also understood as a measure of molecular disorder within a macroscopic system). After an hour, we expect to find a confused situation. Still, it is a statistical truth that, before or after, there will be a moment at which all the red molecules will be in the left part of the box, and all the blue ones in the right. At that exact moment, with the molecular disorder to the minimum again, the experimenter will put the partition back in position. Does it mean that, in that isolated system, time passed backwards when entropy decreased? Or is it the opposite, that with the passage of time – which, in a Relationist account, corresponds to the happening of events – entropy tends to increase?

Think of a video showing what happened inside the box. It wouldn't be possible, for us, to tell whether the video is running forwards or backwards (because the beginning and the end of the video would be the same). This is true, but what's the point? It would be very inconvenient to say that when entropy increased time was running forwards, and when entropy decreased time was running backwards. Even if we observed puddles spontaneously freezing into ice cubes, why should we think that time passed backwards? There's a classical physical explanation, forwards-oriented, of what happened. Our temporal experience is intact. Simply, we have seen something very uncommon, as the particles in the box casually and spontaneously organizing into a left part and a right part, for a mere stochastic reason. We would still preserve the temporal order of the cause-

13 Evans, Gryb & Thebault (2016), p. 22.

effect relation (with causes preceding effects), and that's why I find Price's question (“could – and does – the future affect the past?”[14]) nonsensical. There's no intrinsic direction along a line in movement (forward or backward), but simply motion, events happening. Is the fact that they *could* happen (or even in fact happen) in a different order really important, or is it the very process of acquisition of information that defines, for us, a past and a future?

What I want to claim, then, is that there isn't a direction towards which time is going (there is no arrow of time), and entropy almost always increases because it is statistically simpler. Eternalist accounts that make use of an arrow of time usually envisage a Block universe in which, once we have chosen a point *and* a direction, we can tell what is going to happen: they take an outside perspective and see the entirety of spacetime as an immobile cinematographic film, where all the spatiotemporal stages are spread out, and we have to choose in which direction we want to play the film. What I'm proposing, instead, is to think that, whichever freeze-frame we choose, only two things are possible, to move or not to move. We can consider, from the external perspective, the freeze-frames, but whichever moment we pick, the world has no choice but moving, consuming energy, getting older.

3.The low-entropy past and the banality of chaos

If the entropy of the universe is still increasing, and entropy is a measure of the disorder of a system, how come that the beginning of our universe was so orderly? There are two main problems with this question: the first is that, as I have argued, the expression entropy of the universe, simply, is meaningless – the universe is not a box of particles. The second is that we still don't have – and maybe we will never have – a clear understanding of what “the beginning of the universe” means. A part from the old scholastic question “why is there something instead of nothing?”, even the contemporary, qualitative description of the beginning of the universe involve infinite quantities (singularities), which are maybe good ingredients for a mathematical description of reality, but definitely not for a physical one. What does it mean that all the matter and the energy of the universe were concentrated in one point? Does it really make sense to add to this story the fact that matter and energy had also a very low entropy? All we know (or at least believe) is that after the Big Bang there was a rapid expansion and clumps of matter were formed, which are still exchanging energy with the surrounding environment.

14 Price (1996), p. VII.

This is related to the question of the alleged fine tuning of the fundamental parameters of the universe. I suspect, in fact, that a similar reasoning is responsible for the emergence of the problem of the Past Hypothesis in thermodynamics[15]. If we think of all the circumstances that led our parents to meet, fall in love and have a child at a particular moment, we realize that the probability for us to be born was one in billions. It seems that everything in the universe secretly conspired to make our birth happen - every random action seems extraordinarily *ad hoc* for the organism at the end of the causal chain. The mere fact that our parents could have had a different child doesn't mean that we have to explain why they had us and not our possible brothers. Saying that it was random isn't concealing a deeper truth.

Here, in my opinion, we are underestimating the banality of chaos. The Second Law of Thermodynamics, after all, tells an obvious story. I'm not sure it should even be considered a law of nature, it is merely a statistical truth. Think again of the clouds produced by the man smoking. If you concentrate on the single particles, you lose track of the direction of time, while the same thing is impossible when you consider the entire picture. This is true, but it has a simpler explanation than that of an arrow of time pointing in a certain direction. Consider a lottery (90 possible numbers, 1–90, and six extractions) and these two different extractions:

13 41 2 87 60 35
1 2 3 4 5 6

Obviously, the two sequences have the same probability to be extracted. But there is a clear sense in which the second sequence strikes us as incredible (that's probably why, even if it doesn't make sense, no gambler in the world would ever spend a penny on the second sequence). When we concentrate on the single numbers, we lose track of this amazement. The six (final number drawn), in itself, isn't a shocking result. When we look at the big picture, however, the six strikes us as the perfect fulfillment of a miracle. Why is that so? Because an ordinate and dense sequence is extraordinarily much more improbable that a random one. There are a lot of disordered sequences, that is to say, while there are only a few ordinate ones. The first sequence is just as rare and incredible as the second one, but there is a sense in which it is different, it is part of a much-populated class of random sequences. Even if the two sequences have the same probability to be extracted, that is to say, it

15 See Callender (2001).

is extraordinarily much more probable to obtain a random sequence than an ordinate one, simply because the random sequences are a lot more. I suspect that this is exactly what happens in the case of the man smoking.

If we concentrate on the microphysical events, the single particles moving, we lose track of the big picture, just as if we only considered a number at a time in the case of the lottery. In this sense, it is true that from a physical point of view the process is time-reversal invariant, just as in the case of the lottery it is indifferent to extract a six or a seventy-one. But when we consider the macrophysical situation, it is much more probable that the particles disperse in the air. There is a clear sense in which there is no need of a particular law of nature to see the particles disperse instead of gather, it is simply a matter of statistics. Chaos is infinitely much simpler than order, and the Second Law of thermodynamics simply states this statistical truth, it doesn't impose a direction on nature. That's why we almost never observe the decrease of entropy in an isolated system.

The whole entropic arrow argument seems based on a confusion between the physical possibility to see a very rare process (the opposite of a physical process we are accustomed to), and the alleged possibility to see one and the same process in two different temporal directions. The so-called time reversal invariance of the fundamental laws of physics should be read just as the possibility, for the twenty molecules in the box described above, to casually order themselves spontaneously. It has nothing to do with a direction of time.

This, in turn, is related to the debate about causality. We always see the flame *after* we rub the match. The actual laws of physics seem to inherit Hume's worry that, however, there is nothing forbidding the opposite, that the flame could be the cause of the rubbing of the match. It seems that everything relies on initial conditions, which, the reasoning goes, are not part of the laws of nature, but just define the physical state to which they apply. In a different universe with different initial conditions, its inhabitants could be used to the opposite of what we are used to see, and maintain that it is absurd to think that the rubbing precedes the flame.

It seems that there is no inbuilt asymmetry in the laws of physics, and physical laws only yield concrete predictions when they are coupled to particular boundary conditions, typically formulated as initial conditions. If we assume very special initial conditions, the time-symmetrical laws might still allow only a time-asymmetrical solution. Following this strategy, the direction of the cause-effect relation would not be law-like but due to a contingent feature of our universe. But, as observes Maudlin (2007),

> the laws of nature *alone* suffice to explain almost nothing […]. The models of fundamental physical law are infinitely varied, and the only facts that those laws *alone* could account for are facts shared in common by all the models. In all practical cases, we explain things physically not merely by invoking the laws, but also by invoking *boundary conditions*.[16]

The fact that the reversed order of a physical process is possible doesn't mean that the actual order in which it happens isn't objective. It does not even mean however, as Maudlin implies, that there is an objective, Substantivalist-like, "intrinsic passage of time"[17]. This is a crucial point:

> the motion of an asteroid from Earth to Mars is just a matter of the asteroid being differently situated with respect to those planets at different times […]. Since these are objective, mind-independent facts about space-time worms, the changes are equally objective and mind-independent. The rub, of course, is that the asteroid being differently situated at different times is consistent both with a motion from Earth to Mars and with a motion from Mars to Earth […]. Motions and changes are not merely a matter of things being different at different times, but also critically a matter of which of these times are *earlier* and which *later*. […] If there is no difference in the entropy (e.g. if the universe is in thermal equilibrium), then there is no longer a distinction between Earth-to-Mars and Mars-to-Earth trips.[18]

The travel of the asteroid as we experience it, however, is related to changes in my body (for example, me getting older) that clearly define a trajectory, without the need of a Substantivalist notion of time or the existence of an arrow. The asteroid being differently situated at different times is consistent both with a motion from A to B and the opposite, but a relational notion of change is able to distinguish between the two trips. If I saw the asteroid near Earth when my hair was brown (young man) and near Mars when my hair was white (old man), this clearly defines an earlier and a later. This objective, mind-independent order defines an objective relational time, different to Newton's in that it depends on the actual change of the things that surrounds

16 Maudlin (2007), p. 119.
17 Maudlin (2007), pp. 127–128.
18 Maudlin (2007), p. 128.

us, and doesn't pass *in se et per se*. There is only motion, there isn't a Substantivalist time passing, nor an arrow of time. All we need in such a Relationist account are things moving.

4. There is no arrow of time

As I have argued, the time-reversal invariance of the fundamental laws of physics is often taken to mean that in a Block Universe, even if we are experiencing events as forwards-in-time, it would be perfectly possible to experience them symmetrically, as backwards-in-time. But what does it really mean?

Even setting aside the observed violations of charge parity invariance in the decay of the neutral K meson (a counterexample to the alleged time reversal invariance of the fundamental laws of physics), and supposing that we can understand the time reversal operation without there being an objective direction with respect to which the reversal occurs (you can play a video forwards or backwards, but what about the events you filmed? They must have happened one after the other), what I find really troubling is the idea that events could happen in the opposite temporal direction.

Consider the spatial case. You can move or not move, you can't undo your movement. If you walk 80 meters, you can certainly come back. The result, however, is not 0, but 160 meters. A video, in this case, would just reproduce the illusion I described for the temporal dimension. Playing it backwards, it seems that the person who walked 80 meters could go back to 0. But this is just wrong, moving is always positive.

I believe that this is also the case with the Relational notion of time that I'm trying to defend. Either time passes or not, it can't go in another direction. If we intend time as a measure of change, the world has only two possibilities, stay still or move – just like us when we walk. What I want to claim, then, is that even temporally all we can do is to add meters to our walk. We can not subtract, because there is not a direction towards which time is flowing. As the Shakespearean Hamlet would put this: to pass or not to pass (which, in a relational sense of time, means for things to change, to move). The only difference between time and space, under this point of view, seems to be the fact that while I can stay still in space, I can't do that in time. But this is true only at a common-sensical level. Even when we sit down, we are moving really fast in space (around the terrestrial axis *and* the sun). In General Relativity, moreover, the clear distinction between time and space seems to vanish, moving is always moving in time *and* space. But even if, for the sake of the argument, we kept the conceptual distinction between space and time, it would be possible, although very difficult, to stay still in time (we should totally freeze the universe, as in the famous thought experiment by Sidney Shoemaker, 1969).

If we re-think the whole question under this light, the time reversal invariance of the fundamental laws of physics could be read just as the theoretical possibility that the order of a certain chain of events was different, and not as the possibility that the same order of events happened in a different temporal direction, because there is no such thing as a positive (or negative) temporal direction. As Maudlin points out, the actual possibility of the reversed order of the physical processes we usually see is not to take for granted. It would mean that

> given the actual sequence of physical states of your body over the last ten minutes, the time-reversed sequence of time-reversed states is also physically possible. Somewhere on some other planet (as far as the laws of physics go) some such sequence could exist, unproblematically time reversed relative to the sequence of states that make you up [we can label this strange order of physical states the Doppelgänger point of view]. The visual system* of the Doppelgänger is […] quite unusual: rather than absorbing light from the environment, the retina*s emit light out into the environment. (The emitted light is correlated with the environment in a way that would seem miraculous if we did not know how the physical state of the Doppelgänger was fixed: by time-reversing a normal person.) […] There is no reason to belabor the point: in every detail, the physical processes going on in the Doppelgänger are completely unlike any physical processes we have ever encountered or studied in a laboratory, quite unlike any biological processes we have ever met.[19]

Either the Doppelgänger has a mental state identical to ours, but then it hasn't a different perspective, or the physical processes going on are completely unlike biological processes we have ever met (more magic than science). I take the moral to be that it is an error to concentrate on the microphysical world, forgetting the big picture. As I argued, we would fail to recognize the incredible improbability of an ordinate sequence in the lottery, which is

19 Maudlin (2007), p. 123.

different from the chance of the single sequence – which never changes. Focusing on the particular is not a neutral operation.

Even if we think that we are in a Block Universe and past, present and future events are real, that doesn't mean that we are going from left to right along a temporal line, or that it would be possible to go from right to left. My point, then, is that there isn't an arrow of time, there is not a direction in which time is passing, and thus not any alternative direction. Events are happening – even if I see the disordered particles in the box reorganizing in their respective half, I have seen *something more*, I am older. Why should I think that time is passing backwards? Simply, in an unlikely case like that, entropy would demonstrate its stochastic nature, it would just be another sign of the fact that entropy and time are not related.

To understand why the argument I am trying to make is not circular, please consider the following passage by Huw Price (1996):

> as Boltzmann himself saw […] there is *no* asymmetry […]. The above point about entropy increase toward (what we call) the future applies equally toward (what we call) the past. At a given starting point there are very many more possible histories for the gas that correspond to higher entropy macrostates in its past, than histories that correspond to lower entropy macrostates. Insofar as the argument gives us reason to expect entropy to be higher in the future, it also gives us reason to expect entropy to have been higher in the past. Suppose we find our gas sample unevenly distributed between its two chambers at a particular time, for example. If we consider the gas's possible future, there are many more microstates which correspond to a more even distribution than to a less even distribution. Exactly the same is true if we consider the gas's possible past, however, for the statistical argument simply relies on counting possible combinations, and doesn't know anything about the direction of time.[20]

This is exactly the point. If the past is considered as a temporal locus from which we are moving away, we would be forced to admit that we are actually going in a direction. But what if we, much more radically, considered past every moment at which there were fewer movements (at which our body was less ruined)? It is the charge of circularity itself, at this point, that becomes circular. I am claiming the most parsimonious thing, which is that fewer

20 Price (1996), p. 30.

movements (a less ruined, used brained) correspond to the past. There is no line, no direction, only motion. It would be Price, in this case, that would have to explain in which sense a baby could be in the future of an old man, it would be Price that would have to presuppose the existence of an arrow of time. Why should we describe time as flowing along a uni-dimensional line? It is way simpler a model in which 'past' and 'future' stand for 'fewer movements' and 'more movements'. Let me explain that with a thought experiment.

Imagine an extra-temporal, omnipotent god able to completely stop the change and the motion in the universe and, if you believe that time is a flowing independent entity, stop time. Suppose that this god concentrates on a hot bar of iron on earth, which was placed in a cold box of metal just before the complete stop. If the god did not change anything, the bar would not distribute its heat during this complete stop (since, to do so, the atoms would need to move); but what if the god decided to instantaneously and casually mix the atoms inside the hot-bar-and-cold-box system? For example, suppose he decided to throw three dice – which he created in such a way that he can not predict the result. The first time, the three dice individuate an atom in the system. The second time, the dice tell the god which atom to exchange for the first one. After the extra-temporal god has done this for several times, the entropy of the system is very probably increased, but the world hasn't gone in any direction, it hasn't gone anywhere, indeed. The god, per hypothesis, is extra-temporal, his actions are not going from past-to-future or from future-to-past, they are instantaneous. It doesn't seem that the increase of entropy is connected with a particular direction in which we choose to play the film of reality, but simply to a casual change. It's merely a stochastic reason, it is simpler to disorder a deck of card than to order it. We don't need an arrow of time to explain that.

If we think that there is an arrow of time, we have the problem of explaining why effects always precede causes, why the arrow points in a certain direction. But if we take seriously my proposal, the problem doesn't exist. It would just be a matter of fewer/more movements, and we don't need a direction for that. An old man has done more movements than a baby, it is not a mystery that his consciousness is aligned in the direction baby-to-old man. Do we need an arrow of time for that?

From an Eternalist point of view, there is a four-dimensional, unchanging world. But when you consider a particular point of view (a particular spatio-temporal point), either there are zero degrees Kelvin, or it moves, it changes, it wears out. An atom isn't moving because time is passing, it moves because it has a mass and an energy. It doesn't go in a temporal direction, it simply moves! Does the fact that, from a microphysical point of view, its reversed movements are also possible, automatically imply that it is going towards a specific temporal direction?

What we call time has always a fundamental reference to motion. A day is a rotation of Earth on its axis, a second is a certain number of oscillations of a Cesium atom, and so on. Our consciousness moves because the atoms in our brain move, they don't go in a direction, and there is always a clear sense in which a 70-years-old brain is older than a 20-years-old brain (it is more ruined) that doesn't make reference to the passage of time in itself, or its direction, or its arrow.

The reason why we feel like our consciousness is moving forward is that at every point our consciousness change, with the last acquisition of data. If we think of that as a movement along a line, we naturally think that we are going in a direction. But as I should have shown, there is also the possibility to think that the only two options are to move or not to move. There is no movement of our consciousness on a temporal line. There is just the motion of atoms and the rate at which our brains capture changes in respect to that motion.

Conclusions

In the first paragraph, I claimed that the mere theoretical possibility of time reversal invariance of the fundamental laws of physics is something strongly related to a mathematical, misleading description of our universe. In the second, I maintained that entropy and time are not related, and that the notion of entropy of the universe has many problems in itself. In the third, I argued in favor of the banality of chaos. The Second Law of Thermodynamics, far from being a law of nature, simply states a stochastic truth. In the fourth, I sketched an account in which change is not going in a direction, and defended it from some possible replies.

Some Eternalists claim there is a Block, and we – or our consciousness – are traveling along it in a particular direction, but it is physically possible to also travel in the opposite direction. I answered that there isn't any direction, any arrow. It is simply a mathematical fiction, resulting from the focus on the microphysical particulars instead of the big picture, failing thus to see the banality of chaos. It seems to me the most natural thing is to claim that events simply happen. The fact that they could have happened in a different order does not entail that they happened in a certain direction instead of another. Whichever atom in spacetime you choose, if it has an energy it moves, it is not going in a temporal direction. Many atoms moving randomly result, for mere stochastic reasons, in macro-situations of increasing chaos. There is no direction towards which they are going, there is just moving or not moving, and from a Relationist point of view, motion is not the result of a mysterious independent passage of time, but the passage of time itself.

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