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Dear Professor Price:

I am referring to your book “Time’s arrow and Archimedes’ point” (1996). I support your “double standard fallacy” analysis. Consequently, I do not believe in an intrinsic arrow of time. Nevertheless, there are two minor points of disagreement which might be of interest to you. Let me explain:

When confronted with the old question: *”Why is it that there is no decrease in entropy throughout the whole visible universe, neither in small nor in large dimensions, but only an increase?*”, you would surely reply: “ *There is a permanent decrease, too, but no one we know of can watch it!*”. In other words: From a point of view according to which the universe has no intrinsic direction of time, there is no *absolute* decrease or increase, but only a *change* in entropy. Whether this change is observed as an increase or decrease depends on the perspective. Insofar, you are a follower of Boltzmann’s.

Nevertheless, your view differs from Boltzmann’s in two points:

1) Different from Boltzmann, you do not justify your view (of an intrinsically directionless time) by arguing that the laws of nature, apart from some merely statististical laws, are time-symmetric. Instead, you argue that even in case some of these strict laws were time-*asymmetric*, this would not allow to conclude that the universe has an intrinsic arrow of time. It would just mean that some ficticious representatives of the two opposing (time-reversed) perspectives, when comparing their sets of (non-statistical) laws of nature with each other, would not be able to come to an agreement in every single case, but would have different formulations with respect to at least some of these strict laws. In other words: The relativity principle would not hold with repect to these two “frames of reference”. That’s all. There is no justification for regarding one of the two “frames” as a privileged one. Consequently, there cannot be an intrinsic arrow of time in the universe.

I think your analysis (I hope I got it right) is correct. Nevertheless, one could raise the the following objection: If, due a temporal asymmetry of some (non-statistical) strict laws of nature which govern the functioning of *all* brains, no brain-equipped observer in the second “frame” could ever experience what would be a time-reversal from *our* perspective, a *quasi*-intrinsic arrow of time *would* exist. *Our* arrow of time would then be the only arrow for living beings in the universe. Hence, in order to exclude even a *quasi*-intrinsic arrow of time in the universe, the non-statistical (strict) laws of nature should be time-symmetric. As far as we know, this requirement is met.

2) Your second criticism is as follows: From Boltzmann’s statistical point of view, it is inexplicable why we are finding ourselves in a situation in which entropy increases toward the future, but not toward the past. This cannot be explained by the usual line of thought which goes like this: For instance, the undisputable fact of our existence requires that we find ourselves on the surface of a planet, and not somewhere in empty space (where evolution could not have brought us into existence). Hence, though there is much more empty space than planets in the universe, we should not be surprised to find ourselves where we are. As regards entropy, things

are different, though: Since the past state of the universe surrounding us is endowed with less entropy than the present state, we are under the impression that the present state is far more improbable than is needed to account for our existence. In order to account for our existence, it would have sufficed for nature to put us in an improbable situation of low entropy, but with both the future *and* past representing states of much higher entropy. Such a world would be far less improbable than the one we are actually living in.

You are also right in *this* criticism. But note that Boltzmann himself realized the inconsistency of his purely statistical view. In his paper "Über die mechanische Erklärung irreversibler Vorgänge", Annalen der Physik und Chemie, Neue Folge 60, pp. 392-398 (1897), he writes (I am presenting my own translation):

"*If one refrained from making any presuppositions concerning the present state of the universe, we could not, of course, expect to find the branch-system of the universe, the initial state of which would then be a matter of pure chance, in an improbable state. One would rather expect that it is in a state of thermal equilibrium at its branch-off--point already. Among the few cases in which this expectation does not come true, the most frequent cases would be those in which the state of the system, when being tracked forward or backward (within the branch-system), approaches a more probable state instantaneously. Cases in which the state turns even more improbable over a longer period of time would be much less frequent; such states, however, would occur as often as those states which, when going backward over the same period of time, represent more improbable states*. "

However, only a few pages later, he assumes that we *do* live in such a state – starting from which even "more improbable" states can be found when looking backward – without giving us a clue of how this might come about.

I strongly believe that H. Reichenbach ("The direction of Time"), at this point, has come to the rescue of Boltzmann's concept of time. Different from Hawking's wrong understanding of Reichenbach's position, Reichenbach rejects the idea that causality could serve as an intrinsic arrow of time. Hawking misunderstands Reichenbach's notion of "temporal order" by erroneously identifying it with a "direction of time". Reichenbach argues that there is an intrinsic temporal *order* of events, as otherwise causality would not hold. For instance, if there is, from our perspective, a temporal succession of causally related events A, B, C, then it is an intrinsic feature of B to be *between* A und B; this "betweenness" cannot be altered by switching to the perspective of a temporally reversed observer. But Reichenbach does not have, by any means, an ambition to use causality as a relation that could give proof of an intrinsic *direction* of time: Whether or not A *precedes* C is not an intrinsic feature, but is perspective-dependent.

Reichenbach points out that the different parts of the universe do not behave like a multitude of dice that are cast simultaneously (I am using my own picture here): Different from the latter, the various parts of the universe have a memory: For a given state of the universe (or even of a tiny part of it), it is impossible to assume, in the immediate past or future, a similarly great number of microstates which it *could* assume if its many different parts were all dice. Rather, that number is much, much smaller. Reichenbach compares the situation to that of a mixing of two liquids: It takes time for the two liquids to penetrate each other; therefore the immediate future or past cannot be much different from the present. Boltzmann's purely statistical view is justified only if very, very long intervals of time have elapsed between each of the many pictures of the scene (with each picture standing for a single, simultaneous cast of the multitude of dice). The present state of the universe must hence be explained by the fact the universe started (ended, resp.) by an arrangement of things due to which the laws of nature could not but lead to situation in which we find ourselves. The behaviour of the molecules in my cup of coffee is hence causally influenced by the state of the universe many billion years "away". This is the answer to the question why we are finding ourselves in a situation which, from a purely statistical point of view, is far more improbable than needed for making our existence physically possible.

By the way: A perpetual motion machine of the second kind, if it existed, could not change much. It would, though, help in adopting Boltzmann's / Reichenbach's, and - to the extent described - *your* concept of time: With a perpetual motion machine of the second kind at work, a closed system could, technically, return to any state of the past without having to wait for billions and billions of years until the desired state will re-materialize by pure chance. The shortening of the wait period is, in this context (in which we deal with the nature of time), the only benefit of a perpetual motion machine of the second kind. Given that it would be within our reach to return to any state of the past, the lack of an intrinsic arrow of time would become psychologically compelling, though that lack is visible even without such a machine. Moreover, a perpetual motion machine would make it psychologically compelling that, in order to reduce entropy, a certain arrangement of the elements within a closed system is necessary to start with. The same would then be true for an *increase* in entropy, which is thus the other side of the same medal. Here, too, we do not really need a perpetual motion machine of the second kind to realize the fact that our present state cannot be accounted for by mere statistics alone.

Best
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