From: C. K. Raju, The Eleven Pictures of Time (Sage 2003) pp 298-302

Einstein's Mistake

Relativity changed the notion of the instant; for an instant consists of all events that are simultaneous with it, and relativity changed the notion of simultaneity. But relativity also changed the notion of *instantaneity*; a possible change realised by Poincaré, but not by Einstein who made a mathematical mistake about it—a mistake that he did not correct till the end of his life.

What is instantaneity? Let us begin with the conventional idea that physics provides a 'causal' description of the world by relating causes to effects—physics describes how the state of the world *now* relates to its future states. The arrow continues to fly because of its state at the preceding instant, and physics enables us to calculate the future motion of the arrow, if the present state is known. We saw earlier (p. 178) that this 'causal' interpretation of physics is deceptive. The best argument against such an interpretation is Poincaré's philosophy that physics is defined by its mathematical equations, and not by the interpretations we assign to these equations. Instantaneity means that 'physical law is a differential equation', so that actually the state now decides *both* past and future states, so that all states are decided by the state at any one given instant. Thus, the formulation of physics using differential equations essentially means that the state of the world at any time is decided by its state at any one instant. One may say the arrow is flying now because it was flying a moment ago; with equal facility one may say the arrow is flying now because it will fall to the ground a moment later.

Why not simply say that the arrow is flying now because the archer released it from his bow two seconds earlier? There is a

difficulty if one believes with Aristotle and Augustine that the past has ceased to exist; if so, locating causes in the past would make them non-existent! Therefore, the present motion of the arrow can be linked to the past action of the archer only through an intermediate chain of causes. This belief in the non-existence of the past is incompatible with relativity, as we have already seen—after relativity, the past does not cease to exist. Parts of the past may continue to exist in Buddhism, where the criterion of existence is causal efficacy, and there may be a possible delay between cause and effect. Therefore, Buddhists would say that a past event continues to exist if it has not yet produced its effects.

The Philosophy of Contact

The belief that the past has ceased to exist is closely related to another belief in the desirability of explanation by contact: causes proximate in time are presumably also proximate in space. The philosophy of contact elevates this to a metaphysical principle: a physical explanation *must* locate causes not only in the immediate past, but in the immediate vicinity—the action of one body on another must be explained through physical contact between the two bodies. The archer cannot influence the motion of the arrow after it has left the bow, for he has lost contact with the arrow.

One observes, of course, the interaction between bodies that are evidently *not* in contact—like a pair of magnets. The aether, as an all-pervasive invisible substratum, was first introduced to help explain by contact such observed interactions between two spatially separated bodies. The aether was imbued with all manners of astounding properties to prevent this principle of action-by-contact from being falsified. In present-day physics (including relativity and quantum mechanics), the underlying philosophy of contact is preserved through the notion of the all-pervasive invisible substratum of the field, which has substituted the aether.[1]

made no serious difference. Einstein only half-rejected the aether: he did not reject it in the sense of action by contact or instantaneity.[6] He thought, following Bacon, that action without contact was 'spooky', and stated as much while formulating the Einstein–Podolsky–Rosen paradox (Chapter 8). Poincaré, being a mathematician, understood that rejecting aether would change the equations of physics, making them what he called 'equations of finite differences'.

> Does our ether actually exist? We know the origin of our belief in ether. If light takes several years to reach us from a distant star, it is no longer on the star, nor is on the earth. It must be somewhere, and supported, so to speak, by some material agency…The same idea may be expressed in a more mathematical and more abstract form…in ordinary mechanics the state of the system under consideration depends only on its state at the moment immediately preceding; the system therefore satisfies certain differential equations. On the other hand, if we did not believe in the ether, the state of the material universe would depend not only on the state immediately preceding, but also on much older states; the system would satisfy *equations of finite differences*. The ether was invented to escape the breaking down of the laws of general mechanics.[7] [Emphasis mine.]

Today we would call these 'delay differential equations', or 'functional differential equations'. The names are unimportant, and what is important is this: if aether and action by contact are rejected, then, as a first step, instantaneity has to be replaced by *history dependence*.

Human memory is the simplest example of history dependence. The way in which we respond to a person depends upon whether or not we remember having met that person before. But can't memory be fitted to the paradigm of instantaneity? After all, memory is stored in the brain, so that the state of the brain at this instant incorporates all the memory in it, and it is this state which decides how the interaction proceeds. For any system with memory, one can hope to repeat this analysis because memory is stored somewhere. This account of history dependence, though plausible, tends to be erroneous or misleading— at least in physics[8]

Einstein's mathematical error—an error repeated also by other authors—published in the most reputed journal in mathematics, was exactly this: he believed that history dependence can always be reduced to instantaneity, in a simple-minded way.[9] Einstein took this erroneous mathematical belief to his grave. But this reduction cannot be done, in general, because *instantaneity is time-symmetric, while history-dependence is time asymmetric*. Instantaneity is time-symmetric: that is, the present state of a system, evolving under instantaneity, symmetrically decides both past and future: every state has a unique successor t seconds into the future, and a unique precursor t seconds into the past; distinct past states correspond in a one-to-one fashion with distinct future states. In particular, admitting chaos etc., one can retrodict the past typically to the extent that one can predict the future. This is no longer true with history dependence: past (history) decides the future, but the other way around is impossible, for systems with distinct histories may end up in the same future state (see Fig. 1). *Knowledge of the present state, therefore, does not enable a unique reconstruction of the past history of the system*.