What does science tell us about the nature of time?

Often the most ubiquitous things are the most perplexing and this is certainly true of time. Many will empathize with St.Augustin who said that "What then is time? If no one asks me, I know what it is. If I wish to explain it to him who asks, I do not know." Time has always been central to philosophical debates but it is also a big topic in science. This is not only because science strives to explain time just like thunderstorms or any other phenomena, it also requires a good understanding of time because it serves as an incredibly helpful explanatory tool itself.

Two questions are most pressing when dealing with time: **1. Is time fundamental? 2. Why does time appear to have a direction?** Before we look for answers, however, let us pause to ask what it means for something to be "fundamental". We think of something as fundamental if it appears as a parameter in our most accurate and complete description of the world. For example, if we found that we could describe and predict every observable phenomenon in terms of jelly beans, then jelly beans would be fundamental. So what about time? Unfortunately we don't have a single theory of everything to decide what is fundamental and what isn't. Hence, to answer our first question the best we can do is to turn to our current leading theories. Here we'll concentrate on **relativity theory** and **thermodynamics**.

Possibly the most ground-breaking discovery about time in the 20th century is that two observers may measure the duration of the same process to be different depending on how fast they move with respect to that process - a finding that forces us to reject the naive idea that time is absolute and independent of what happens in the universe. The key to this **relativity of time** is that there is a finite upper limit for the speed of objects - the speed of light. To understand how profound this limit is, it is important not to think of light particles as being like a normal object simply moving much faster: To a light particle, time and space do not exist in any meaningful way, rather they exist for anything else *only because* they do *not* exist for light. Think of this as an, admittedly funny, physical analogy to how we can use any word to define what a "chair" is except for "chair" itself. In this sense, in relativity theory **time is not fundamental**, since the speed of light explains time but not vice versa.

Inspired by this we can go even further: That there is a finite speed of light means that there are regions of space-time that cannot possibly affect each other. Given that light takes about eight minutes to travel from the sun

to Earth, nothing happening at the sun right now can possibly affect what I do over the next eight minutes. If the speed of light was infinite, this would not be true. Thus, time appears as the space-time dimension in which systems influence another. We could then again reason backwards and take (space-)time to be a manifestation of the very intuitive belief about our universe that **not everything can depend on everything**.

But what about the **direction of time**? Given that light travels at the same speed in the past as it does in the future, we still haven't explained why we experience time to be going from past to future only. Enter thermodynamics, the study of how systems evolve into equilibrium: If I asked you to order in time two photographs, one of a glass on a table and the other of shards of glass on that table, you'd probably leave them in that order. We've all seen glasses turn to shards but never the other way around. Let's try to think of this fact in the following way: What is the number of possible ways for a glass to be broken? Infinitely many. And how many ways are there to combine the shards into a glass? Very few! So there are many more ways for the world to change such that glasses are broken than being formed and this **asymmetry** is what we observe as the direction of time!

If you asked a child what time is, they respond something like: "Time is how things change". After this brief survey of some of what modern physics has to say about time, we see that the child's statement is scientifically better supported than its naivety might suggest. Time seems to be a manifestation of the fact that physical systems have **limits to how they can influence** each other. Whether this would solve St.Augustin's problem is another question.

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