ABOUT TIME

And yet it moves.

Galileo Galilei (1633)

The infinite divisibility of space implies that of time, as is evident from the nature of motion.

David Hume (1739)

We are simply using the wrong variables.

Antony Valentini (1996)

This moment here is the only observable time and place. Nothing in known physics corresponds to the passage of time. … Is there a key quality of time that science has not yet identified?

Paul Davies (2002)

Newton's much misunderstood and greatly maligned distinction between absolute and relative time deserves our thoughtful consideration.

William Craig (2008)

Concepts like "time" are not handed to us unambiguously by the outside world but are invented by human beings trying to make sense of the universe.

Sean Carroll (2010)

Galileo is speaking—*sotto voce* I assume, as he knows the Inquisition's beady eye and sneaky ear are on him—of a moon of Jupiter. He means its spatial motion. But he might as well be speaking about time, the flow of time within which he sees it move. He thinks motion shows time flows. He tries to prove it.

Nearly four hundred years later many physicists believe it doesn't. Frank's Beginning says they're wrong. It says the universe contains a clock to prove it. More to the point, it *is* the clock. It ticks more than 10 million trillion trillion trillion times a second. Its ticking moves what we call time along.

And so, time does exist. And it *does* flow.

Last night I slept for hours. It's been a three-cup wake-up so far and I still feel groggy. He's in strong and silent mode. Or does *he* sleep? Apart, I mean, from me?

It's funny how perverse a guy like me can be. For months each time her Frank walks in I'm irritated. It's like he's intruding. There's no rhyme or reason

to it; only chemistry. Now as I let myself in I know no one else will pass the door today. And so the place feels different. It's become a lonely zone here with the whole world parked outside. I hesitate to say I miss him. But as I settle down to write it is an effort in a way it didn't seem to be before. All the more because today I have to tackle time and space again and my Frank too seems to be missing. He must of course be there, wherever there may be. But I'm adrift, a feeling that I've had before, a feeling that I haven't had though since I took the job. To escape from it I turn back to the books. Not paper books; the Web.

It is, so several sites inform me, 1983 in Sévres, the 17th *Conférence Générale des Poids et Mesures*. Members vote for Resolution 1. In maybe twenty words it redefines the meter: 'The metre is the length of the path travelled by light in vacuum during a time interval of 1/299792458 of a second.'

It's a fundamental change: Henceforth one checks one's ruler with a stopwatch, so to speak. *CGPM* delegates are all small-c conservative. So no surprise to find that there is solid reason behind this strange-sounding step. It's this: Time measurements are more precise than measurements of length.

There is no evidence that any of the delegates were thinking of cosmology. Yet they did something odd to it. They redefined 4-D Spacetime so all of its dimensions are expressed in terms of time. It's confusing, so I'm glad that ex-LAPD is AWOL. He had just begun to get the hang of special relativity, or so I thought, when I revealed that 3-D space and 1-D time were giving way to 4-D space-like Spacetime. Then I had to break the news that Spacetime can be curved. How could I explain that its dimensions are all measured using clocks?

So, if time is now a distinct—maybe even senior—dimension, how fast does the CC tick? One could say that it ticks so many times per second. But what's a second? Any fundamental answer will amount to saying it's so many ticks. And what's a tick? Well, it's a Tock. If it has time it is the Planck time, an extremely tiny fraction of a second. How to break the circle? Space looks like the only place to go.

So how does space relate to time? The ratio of space to time is motion. How does an object, say a particle, move in a space that's made of Flecks in time that's made of Tocks? If, I think—but promptly park this too—a particle's a thing that *can* be followed in his space, it moves to an adjacent Fleck at the next Tock. Or not. These seem to me to be the choices. So top speed for a particle is one Fleck per Tock. It's the ratio of space to time and only incidentally a limit.

"What does this do to the speed of light?"

It's good to hear his voice and I am thinking it does nothing. In fact it fits it fine. The Fleck size if it has size must be the *Planck length*, about 1.6×10^{-35}

meters. Divide by the Planck time, 5.4×10^{-44} seconds. This is not exactly new. As Susskind puts it:

> It is to Planck's everlasting credit that he realized that such impossibly tiny dimensions must play a basic role in any ultimate theory of the physical world. He didn't know what that role would be, but he might have guessed that the smallest building blocks of matter would be 'Planck sized.'

Planck scale invokes this ratio, one Fleck/Tock. It is about 300,000,000 meters per second, which is what, for reasons more of history than physics, physics calls the speed of light. This is neither deeply meaningful nor a coincidence. The Planck time is defined, by an outfit called *CODATA*, as the Planck length divided by *c*. So one Fleck per Tock is automatically equal to the speed of light. It is made to be so when CODATA defines time in terms of length. Do they have it backwards?

Back to the delegates and their decision at the 17th CGPM. They effectively define the speed of light as *exactly* 299,792,458 meters per second. This is *not* like the 1897 Bill to define pi as *exactly* 3 which passed the State of Indiana House of Representatives and, contrary to legend that it once was law, failed in the Senate on the final vote.

The reason why it's different is this: If the speed of light is ever measured as being even slightly more or less than 299,792,458 meters per second, the CGPM delegates will shrink or stretch the *meter*; they will make it so again. Unlike the Indiana Legislature they have jurisdiction; like Captain Picard, they *can* make it so. But my friend should note again the way they do it—not by defining time in terms of length but by defining length in terms of time.

What do I want him to take home from this? Well, it seems that CGPM has it spot-on and CODATA has its money on a lazy horse. The Beginning says that time is what it is. It rests on a natural number—a number of Tocks. No one can vary it or tune it up. Its writ runs everywhere. It is the universe's pace whether we measure it or not. Carroll is both right and wrong. Wrong because the universe invented its time long before we came to ponder. Right in that the universe does not hand its time to us unambiguously or at all. We can't hide from the Cosmic Clock but it does hide from us. The only way to take a peek is: Make a move.

"How much time is a Tock?"

Well I just now said it should be 5.4×10^{-44} seconds. But his question throws me back to circularity in time. It may be convenient to *think* about a Tock in terms of seconds. But now that I think of it, a Tock is not a measure. It is an event, a card dealt by a dealer, one step in a sequence. As far as *it*'s concerned it has no *size*. Another answer to his question is 1.6×10^{-35} meters. It

takes us back to using motion as a way to measure time. It takes me back into confusion.

Aside from making it all go, how *does* the Tock affect our world? I try a thought experiment: I slow the Cosmic Clock like water getting into Buddy's watch and gumming up its works. If the time length of a Tock should double, could we tell that things were not the same? Well, it seems we could: The speed of light, the ratio of space to time, in Flecks per Tocks, would become slower. It would be half its former value if Tocks started taking twice as long. This looks good for all of fifteen seconds and then crumbles into a *gedanken*heap. It's fundamental that the ratio is one. And I went this way already. It's BUDDY.BAS, on power-save, as seen inside by my—like Buddy's—eye.

And yet it bothers me. What if the time length of a Tock *is* changing? What if the Cosmic Clock is running down? What if we don't notice? Google always knows. A search on speed+light+decreasing garners a few million hits! Digging deeper I hit pay dirt: Searching arXiv finds me papers on cosmologies that have decreasing light-speeds. Seems my question has some merit. My sense of accomplishment does not last long.

"How can we measure the timespan of a Tock?"

He hits a nerve. It's clear to me that 'measure' means directly. I can't think of any way it can be done.

"What's the value of a unit we can't measure?"

I am boxed into a corner that I should not be in.

"A Tock defines one step in a sequence. How does it get to be a piece of time?"

Well, when he puts it that way, maybe it doesn't. But how does time get to be?

"It doesn't happen."

He can't do this to me. Panic vies for my attention. We've been building this whole edifice around the way that Tocks turn into time.

"Time is just the way it seems to be. Our minds invent it to explain experience."

I reach. I grasp. I think I get it. We see clocks. We say their ticks show seconds. Of these ticks the universe knows nothing. It Tocks. With Tocks it Moves the clumps of particles that we call clocks. It's not lots of Tocks that make up what clock-watchers call a second. It's not Tocks, it's *clocks* that are my problem! They don't tell time. They tell motion.

Suddenly the answer to Smart's question about flow of time—seconds per *what*?—strikes me as so obvious it leaves a strange sensation: It's seconds per

Tock! And the beauty of it is that, though we can't detect a Tock directly, QM's ready with an unreal number: roughly 5.39124×10^{-44} seconds.

So the thing about Tocks taking longer is the wrong question. It's not about how long Tocks take. It's about the length of seconds. Longer Tocks is just another concept with no meaning. For us to see a change the change would have to be in Fleck-steps that a particle can *jump* per Tock; in other words, the Rules.

From the Beginning I now know that size is volume; it's not length. It is measured by a quantum number: Count the Flecks. It too is what it is. Length has no exact existence. In this universe it is not actual. It too is man-made. It is what we choose to make it. It is sensible for CGPM to define it based on time. In doing so, they use the speed of light. At true quantum scale, the speed of light *does* have a real or quantal meaning. It's the ratio between two natural numbers. It's one over one, one Fleck per Tock. In other words, its value is exactly one. But beyond the next Fleck it has only statistical significance. It is just as Hawking prophesied in 1980: 'Even if we find a unified theory, we may be able to make only statistical predictions.'

So length is not only *not* continuous, it has no useful meaning at true quantum scale. In fact, position, the dimension of dynamics, is the *wrong variable* for a real quantum theory. Distance is for driving, length is practical in carpentry, position can be seen under a microscope—but, just as pressure conceals what the molecules are doing, position is worse than useless when it comes to understanding how things actually work. It emerges from statistics of a lot of Flecks.

"So is relativity all wrong?"

My first thought is, though he said 'so', he's changed the subject. My second is: I don't like him pitching questions like this at me. And then: It's your Beginning; how would I know? And then I realize he likely caught all three thoughts but I'm glad he asked. I'm glad he's *here* to ask. And finally I realize maybe I *do* know. Or at least can work it out.

Tock time won't stop anyone from using any Frame of Reference and any time they choose. It affects no one. Nobody tells Tock time. Its clock runs the universe but it is hidden. It's the system's time, to use Rovelli's term—not the observer's time. And here the system is the universe.

Rovelli makes two points on time and physics. Of GR he says that it 'is *structured* in such a way to imply that there is something *external* to the system described.' And, in QM, he says, 'The very notion of a system's state depends on the fact that an observer is observing it.'

So neither works when *nothing* is outside the system or, as my detective

who can claim he took a look would have me say, *not even* nothing. Does physics arrogate a sway over their system time it can't live up to when the system is the universe? That Tolkien line leaps luminous to mind again: '*His* cat he calls her, but she owns him not.'

This would be his answer to those physicists—and those philosophers—who want to do away with time. The thing that drives them is there is no way to fashion a direct connect from Tock to clock. Their clocks will not tick Tock-time. A clock is measured motion. A tick clock measures moving hands. A chic clock measures moving charges. New optic clocks will measure moving photons. The world's best clock tracks photons from a single atom of aluminum; it keeps time to several seconds in a billion years. Photons in such clocks use lots of Flecks to link to lots of Tocks. Thus time is emergent and statistical. Thus too each timepiece has its movement.

How then does time tie to causes and effects? Fleck-scale causes take their chances so Fleck-scale effects are random. What then is a cause, what an effect? It is Laplace who, in 1820, says, 'We should regard the present state of the universe as the effect of the preceding state and as the cause of the state that follows.' What does my Frank say today? Exactly!

At the far-far-larger scale of atoms, odds emerge as laws of physics. But they are all odds behind the scene and, so, they're causal but they're not deterministic. This is his point of departure from the current doctrine, of which Carroll writes: 'If our understanding of the fundamental, microscopic laws of nature is correct, we can specify the state of the universe at any time, and from there derive both the past and the future.' He's correct, but the Beginning shows our understanding *isn't*. We regard the laws of nature as exact and thus deterministic. The Beginning shows this up as an illusion. It's a very good one but, up close, one sees the croupier.

"So is relativity all wrong?"

It seems he's not about to let go of this question. But he knows it's more complex than that. Relativity is built on space that is continuous; we know that's wrong but then, at scales where relativity is useful, the mistake can't be detected. Likewise differential equations don't reflect reality so the equations of GR are wrong in principle but then, at scales where relativity is useful, they give good numbers. It's like Newton's theory: It's wrong, but good enough—don't go too fast. Relativity is wrong, but good enough—don't look too close, don't look at points in particles or in black holes, don't look at the beginning.

I take his silence as assent. But soon I sense that he's just waiting. Wearily I rethink all my thoughts and realize that isn't what he's saying. He means the *principle* of relativity. Is he asking whether absolute space makes it obsolete? I

don't know and so another sudden rush of almost-panic hits me and it takes a minute to subside. I try to think it out. What does his absolute space do to relativity? Think Flecks, I tell myself. What would Einstein do with them? What could they do to Einstein? But my thoughts of Flecks lead on to nothing.