From the fixed past to the tangible present to the undecided future, it feels as though time flows inexorably on. But that is an illusion  

By Paul Davies

THAT MYSTERIOUS FLOW

"Gather ye rosebuds while ye may, Old Time is still a-flying."
So wrote 17th-century English poet Robert Herrick, capturing the universal cliché that time flies. And who could doubt that it does? The passage of time is probably the most basic facet of human perception, for we feel time slipping by in our innermost selves in a manner that is altogether more intimate than our experience of, say, space or mass. The passage of time has been compared to the flight of an arrow and to an ever rolling stream, bearing us inexorably from past to future. Shakespeare wrote of "the whirrligig of time," his countryman Andrew Marvell of "Time's winged chariot hurrying near."

Evocative though these images may be, they run afoul of a deep and devastating paradox. Nothing in known physics corresponds to the passage of time. Indeed, physicists insist that time doesn't flow at all; it merely is. Some philosophers argue that the very notion of the passage of time is nonsensical and that talk of the river or flux of time is founded on a misconception. How can something so basic to our experience of the physical world turn out to be a case of mistaken identity? Or is there a key quality of time that science has not yet identified?

Time Isn't of the Essence

In daily life we divide time into three parts: past, present and future. The grammatical structure of language revolves around this fundamental distinction. Reality is associated with the present moment. The past we think of as having slipped out of existence, whereas the future is even more shadowy, its details still unformed. In this simple picture, the "now" of our conscious awareness glides steadily onward, transforming...
TO BE PERFECTLY HONEST, neither scientists nor philosophers really
know what time is or why it exists. The best thing they can say is that
time is an extra dimension akin [but
not identical] to space. For example,
the two-dimensional orbit of the
moon through space can be
thought of as a three-dimensional
corkscrew through spacetime.

Events that were once in the unformed future into the concrete but fleeting reality of the present, and thence relegating them to the fixed past.

Obvious though this commonsense description may seem, it is seriously at odds with modern physics. Albert Ein-
stein famously expressed this point when he wrote to a friend,
"The past, present and future are only illusions, even if stub-
born ones." Einstein's startling conclusion stems directly from his special theory of relativity, which denies any absolute, uni-
versal significance to the present moment. According to the
theory, simultaneity is relative. Two events that occur at the
same moment if observed from one reference frame may oc-
cur at different moments if viewed from another.

An innocuous question such as "What is happening on
Mars now?" has no definite answer. The key point is that
Earth and Mars are a long way apart—up to about 20 light-
minutes. Because information cannot travel faster than light,
an Earth-based observer is unable to know the situation on
Mars at the same instant. He must infer the answer after the
event, when light has had a chance to pass between the plan-
ets. The inferred past event will be different depending on the
observer's velocity.

For example, during a future manned expedition to
Mars, mission controllers back on Earth might say, "I won-
der what Commander Jones is doing at Alpha Base now." Looking at their clock and seeing that it was 12:00 P.M. on
Mars, their answer might be "Eating lunch." But an astron-
aut zooming past Earth at near the speed of light at the same
moment could, on looking at his clock, say that the time on
Mars was earlier or later than 12:00, depending on his di-
rection of motion. That astronaut's answer to the question
about Commander Jones's activities would be "Cooking
lunch" or "Washing dishes" [see illustration on page 46].
Such mismatches make a mockery of any attempt to confer
special status on the present moment, for whose "now" does
that moment refer to? If you and I were in relative motion,
an event that I might judge to be in the as yet undecided future might for you already exist in the fixed past.

The most straightforward conclusion is that both past and future are fixed. For this reason, physicists prefer to think of time as laid out in its entirety—a timescape, analogous to a landscape—with all past and future events located there to answer “One second per second” tells us nothing at all. Although we find it convenient to refer to time’s passage in everyday affairs, the notion imparts no new information that cannot be conveyed without it. Consider the following scenario: Alice was hoping for a white Christmas, but when the day came she was disappointed that it only rained; how-

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together. It is a notion sometimes referred to as block time. Completely absent from this description of nature is anything that singles out a privileged special moment as the present or any process that would systematically turn future events into present, then past, events. In short, the time of the physicist does not pass or flow.

**How Time Doesn’t Fly**

A number of philosophers over the years have arrived at the same conclusion by examining what we normally mean by the passage of time. They argue that the notion is internally inconsistent. The concept of flux, after all, refers to motion. It makes sense to talk about the movement of a physical object, such as an arrow through space, by gauging how its location varies with time. But what meaning can be attached to the movement of time itself? Relative to what does it move? Whereas other types of motion relate one physical process to another, the putative flow of time relates time to itself. Posing the simple question “How fast does time pass?” exposes the absurdity of the very idea. The trivial ever, she was happy that it snowed the following day. Although this description is replete with tenses and references to time’s passage, exactly the same information is conveyed by simply correlating Alice’s mental states with dates, in a manner that omits all reference to time passing or the world changing. Thus, the following cumbersome and rather dry catalogue of facts suffices:

- December 24: Alice hopes for a white Christmas.
- December 25: There is rain. Alice is disappointed.
- December 26: There is snow. Alice is happy.

In this description, nothing happens or changes. There are simply states of the world at different dates and associated mental states for Alice.

Similar arguments go back to ancient Greek philosophers such as Parmenides and Zeno. A century ago British philosopher John McTaggart sought to draw a clear distinction between the description of the world in terms of events happening, which he called the A series, and the description in terms of dates correlated with states of the world, the B series. Each seems to be a true description of reality, and yet the two points of view are seemingly in contradiction. For example, the event “Alice is disappointed” was once in the future, then in the present and afterward in the past. But past, present and future are exclusive categories, so how can a single event have the character of belonging to all three? McTaggart used this clash between the A and B series to argue for the unreality of time as such, perhaps a rather drastic conclusion. Most physicists would put it less dramatically: the flow of time is unreal, but time itself is as real as space.

**What Is Time, Anyway?**

Saint Augustine of Hippo, the famous fifth-century theologian, remarked that he knew well what time is—until somebody asked. Then he was at a loss for words. Because we sense time psychologically, definitions of time based on physics seem dry and inadequate. For the physicist, time is simply what [accurate] clocks measure. Mathematically, it is a one-dimensional space, usually assumed to be continuous, although it might be quantized into discrete “chronons,” like frames of a movie.

The fact that time may be treated as a fourth dimension does not mean that it is identical to the three dimensions of space. Time and space enter into daily experience and physical theory in distinct ways. For instance, the formula for calculating spacetime distances is not the same as the one for calculating spatial distances. The distinction between space and time underpins the key notion of causality, stopping cause and effect from being hopelessly jumbled. On the other hand, many physicists believe that on the very smallest scale of size and duration, space and time might lose their separate identities. —F.D.

**Just in Time**

A great source of confusion in discussions of time’s passage stems from its link with the so-called arrow of time. To deny that time flows is not to claim that the designations “past” and “future” are without physical basis. Events in the world undeniably form a unidirectional sequence. For instance, an egg dropped on the floor will smash into pieces, whereas the reverse process—a broken egg spontaneously assembling itself into an intact egg—is never witnessed. This is an example of the second law of thermodynamics, which states that the entropy of a closed system—roughly defined as how disordered it is—will tend to rise with time.
All Time Like the Present

ACCORDING TO conventional wisdom, the present moment has special significance. It is all that is real. As the clock ticks, the moment passes and another comes into existence—a process that we call the flow of time. The moon, for example, is located at only one position in its orbit around the earth. Over time, it ceases to exist at that position and is instead found at a new position.

Researchers who think about such things, however, generally argue that we cannot possibly single out a present moment as special when every moment considers itself to be special. Objectively, past, present and future must be equally real. All of eternity is laid out in a four-dimensional block composed of time and the three spatial dimensions. (This diagram shows only two of these spatial dimensions.) —P.D.

![Diagram of the Block Universe and the Conventional View](image)

An intact egg has lower entropy than a shattered one. Because nature abounds with irreversible physical processes, the second law of thermodynamics plays a key role in imprinting on the world a conspicuous asymmetry between past and future directions along the time axis. By convention, the arrow of time points toward the future. This does not imply, however, that the arrow is moving toward the future, any more than a compass needle pointing north indicates that the compass is traveling north. Both arrows symbolize an asymmetry, not a movement. The arrow of time denotes an asymmetry of the world in time, not an asymmetry or flux of time. The labels “past” and “future” may legitimately be applied to temporal directions, just as “up” and “down” may be applied to spatial directions, but talk of the past or the future is as meaningless as referring to the up or the down.

The distinction between pastness or futureness and “the” past or “the” future is graphically illustrated by imagining a movie of, say, the egg being dropped on the floor and breaking. If the film were run backward through the projector, everyone would see that the sequence was unreal. Now imagine if the film strip were cut up into frames and the frames shuffled randomly. It would be a straightforward task for someone to rearrange the stack of frames into a correctly ordered sequence, with the broken egg at the top of the stack and the intact egg at the bottom. This vertical stack retains the asymmetry implied by the arrow of time because it forms an ordered sequence in vertical space, proving that time’s asymmetry is actually a property of states of the world, not a property of time as such. It is not necessary for the film actually to be run as a movie for the arrow of time to be discerned.

Given that most physical and philosophical analyses of time fail to uncover any sign of a temporal flow, we are left with something of a mystery. To what should we attribute the powerful, universal impression that the world is in a continual state of flux? Some researchers, notably Nobel laureate chemist Ilya Prigogine, now at the University of Texas, have suggested that the subtle physics of irreversible processes make the flow of time an objective aspect of the world. But I and others argue that it is some sort of illusion.

After all, we do not really observe the passage of time. What we actually observe is that later states of the world differ from earlier states that we still remember. The fact that we remember the past, rather than the future, is an observation not of the passage of time but of the asymmetry of time. Nothing other than a conscious observer registers the flow of time. A clock measures durations between events much as a measuring tape measures distances between places; it does not measure the passage of time.

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