Einstein, Batman, and the Surfer

A Skeptical view Of Time Travel

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IN THE EARLY 1900S THE FRENCH POET and novelist, Guillaume Apollinaire, wrote a story entitled "Le Roi Lune" (the Moon King). In his tale a belt with fantastic powers allows its wearer to make love to all women of all centuries. If that isn't "getting around" I don't know what is.

For many decades science-fiction writers have been imagining the possibility of time travel. More recently, science writers, and even physicists, have been addressing the subject. Seriously. For his book and film *Contact*, Carl Sagan consulted Caltech physicist Kip Thorne, who subsequently developed the idea of using "wormholes" for time travel. Stephen Hawking has devoted many pages to time travel in his popular books. In 1999 the mathematical physicist Paul Davies published his book *How to Build a Time Machine* (see review this issue). In 2001 Princeton astrophysicist Richard Gott came out with *Time Travel In Einstein's Universe*. And in 2002 *Scientific American* devoted a special issue to "The Matter of Time" that included a not-so-skeptical discussion on time travel by Davies.

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Is the hoopla over time travel justified?

To answer that question it is necessary to understand what time travel is—at least the type of time travel physicists contemplate. And to do that—to understand the time travel permitted by the Theory of Relativity—we've got to go over some background, particularly the transition in thinking that occurred when Einstein profoundly amended Newton's model of the universe.

To be brief, we'll focus on the two most important elements of our topic: "speed" and "time." In Newton's universe, speed was understood as relative, but time was absolute. In Einstein's universe one speed, the speed of light, is absolute, while time is now relative. What led to this dramatic turn about?

Batman, Fast Goose, and the S.S. Roswell: Understanding Relativity

Let's begin with the relativity of speed. As a warm-up, consider this riddle:

> Batman is driving the Batmobile at 100 mph, flames shooting out the back. He's pursuing his archenemy, the Penguin. The Penguin is somewhere on the streets of Gotham City, behind the wheel of a black, oversized, gas-guzzling, diabolic SUV. Thanks to Alfred, the trusty butler, Batman learns of the Penguin's whereabouts. He sends the Batmobile careening around one corner, screeching around another. Batman sets his sight on the Penguin's vehicle, and while doing 80 mph, he hits it. Upon later inspection, we discover that neither vehicle has been visibly damaged. How is this possible?

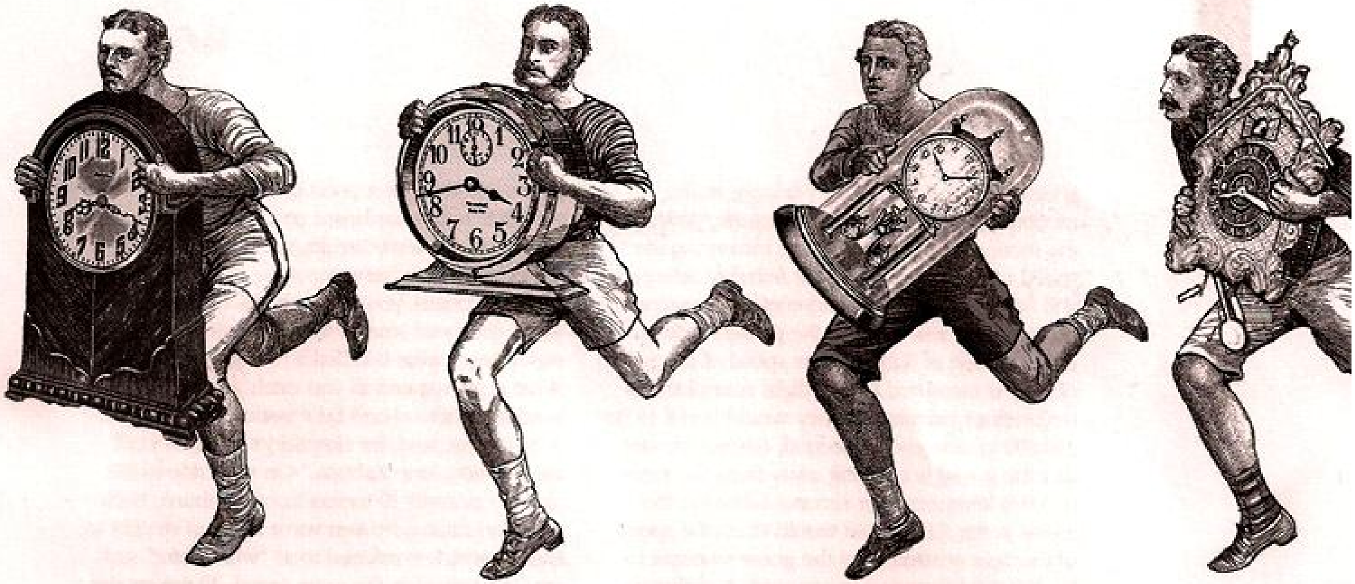
If you don't know the answer, I'll give you a hint—human beings habitually consider the ground to be the primary, or the default, frame of reference. But there is more than one frame of reference.

Now have you figured it out?

If you answered something like, "Gad zooks, Batman, the Penguin was traveling in the same direction at 78 mph!" consider yourself a recipient of an honorary Robin award.

Motion, and therefore speed, is relative. If we want to know how fast something is traveling, we must remember to ask, "according to what frame of reference?" In the above case, in order to understand the physics of the collision, it doesn't matter what Batman's speed was relative to the ground (80mph). What matters was Batman's speed relative to the Penguin. And that speed (80-78 mph) was 2 mph—which is why no appreciable damage was done to either vehicle. And it is also why the Penguin lived to harass the Dynamic Duo another day.

What follows is another example of the rela-



tivity of speed. We'll use this example to illustrate the transition from Newton's to Einstein's model of the universe.

Imagine there is a goose flying north of an airport at 30 mph. This 30 mph is relative to the ground, and, consequently, to the airport control tower. Heading south at 300 mph, straight for the runway—and, unfortunately, the goose—is a Boeing 747. Painted in large, bold letters along the side of the aircraft are the words, "Cuisinart Airlines."

To the question, "At what speed is the goose traveling?" we have to add the question, "According to which frame of reference?" To the customary, default frame—meaning the earth and the control tower—the goose's speed is 30 mph. But according to the goose, the goose's speed is zero. Relative to the goose, the goose forever remains at $x = 0$, $y = 0$ and $z = 0$. According to the 747's frame of reference, the goose's speed is an astonishing 330 mph (300 mph +30 mph). That's quite a speed for a goose. But it's true; if the jetliner's co-pilot were to use a radar gun to measure the speed of the goose, the co-pilot would find the goose was approaching the jetliner at 330 mph. This may seem to be an awkward way of looking at things because we are so accustomed to considering the earth to be the true frame of reference. This problematic habit of ours will come into play when we later examine the nature of time travel. But back to the goose.

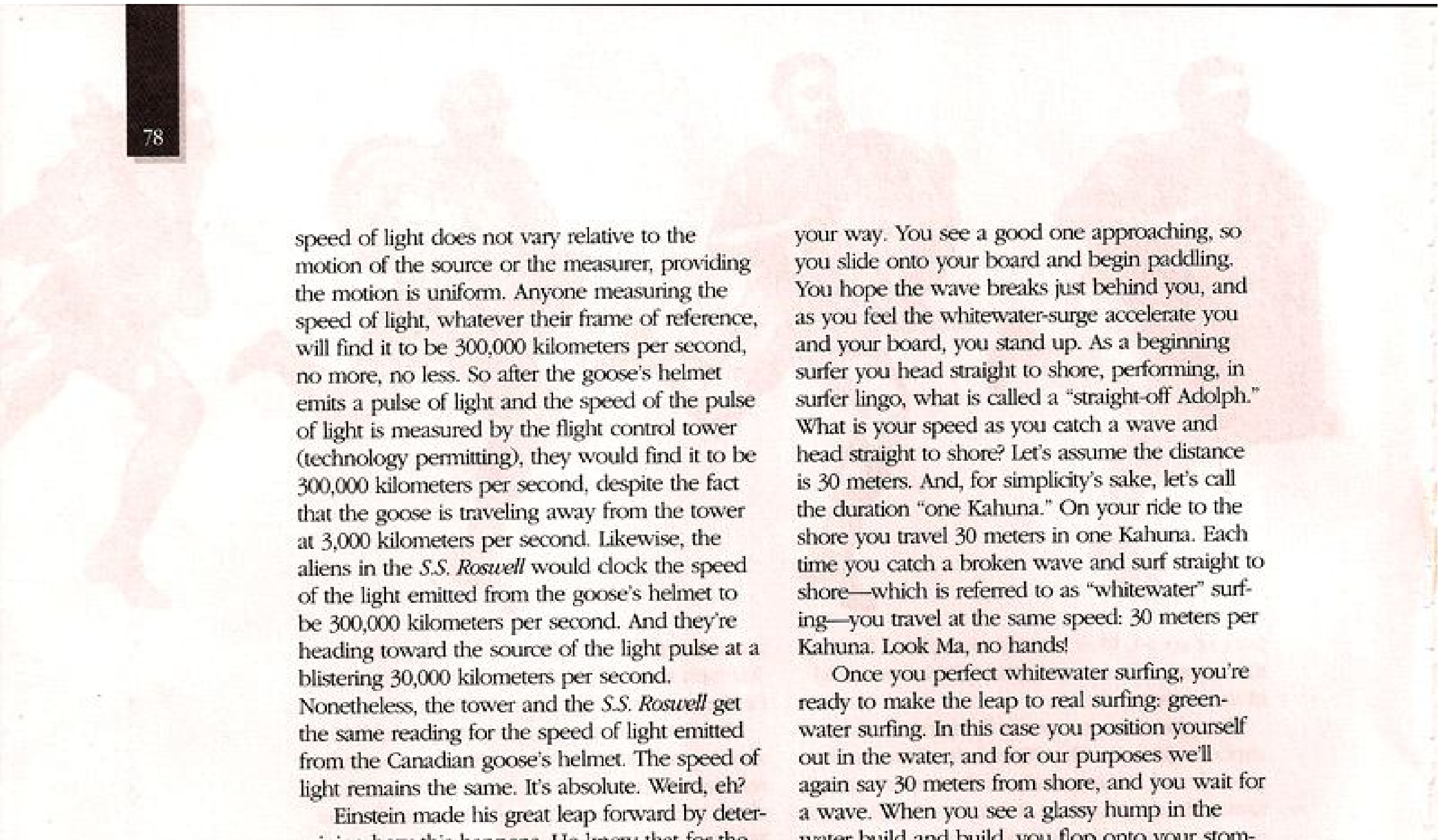
According to the goose's frame of reference, the jetliner is moving towards it at 330 mph. And, in terms of the ensuing collision, it doesn't matter whether the goose is stationary, and the 747 hits it at 330 mph, or the jet is stationary, and the goose collides with it at 330 mph, or the goose travels at 30 mph north and the jetliner 300 mph south. The physical consequences will be the same: one ugly batch of pâté.

In Newton's model of the universe, questions about speed had answers relative to a particular reference frame. This was not true for questions about time. Newton believed time was absolute. Which means that 'when' something happened did not depend on the question, "according to which reference frame?" There was only one time—one master clock, you might say.

Perhaps Einstein's greatest achievement was his realization that time was not absolute but relative. To demonstrate the meaning of this radical breakthrough, we're going to have to reincarnate the goose.

Now imagine a Canadian goose capable of flying at supersonic speeds. Because it is a Canadian goose, it moves in metric units. The goose is winging north of the airport control tower at 3,000 kilometers per second. We're talking one speedy waterfowl. Flying south, toward the airport runway and the goose, there's a UFO. We'll call it the *S.S. Roswell.* The UFO is traveling at a mind-boggling 30,000 kilometers per second. Because the goose flies at such a rapid speed, the law requires him to wear a helmet. (It's uncertain as to whether the aliens are wearing helmets. It's uncertain whether or not aliens even have heads.) On top of the goose's helmet there is a powerful bulb that emits flashes of light.

Thanks to the pioneering work of Maxwell and Lorentz, Einstein knew that the speed of light is invariant; it doesn't change. That is why it is called absolute. The speed of light is the same for all observers, and that speed is roughly 300,000 kilometers per second in a vacuum. The



speed of light does not vary relative to the motion of the source or the measurer, providing the motion is uniform. Anyone measuring the speed of light, whatever their frame of reference, will find it to be 300,000 kilometers per second, no more, no less. So after the goose's helmet emits a pulse of light and the speed of the pulse of light is measured by the flight control tower (technology permitting), they would find it to be 300,000 kilometers per second, despite the fact that the goose is traveling away from the tower at 3,000 kilometers per second. Likewise, the aliens in the *S.S. Roswell* would clock the speed of the light emitted from the goose's helmet to be 300,000 kilometers per second. And they're heading toward the source of the light pulse at a blistering 30,000 kilometers per second. Nonetheless, the tower and the *S.S. Roswell* get the same reading for the speed of light emitted from the Canadian goose's helmet. The speed of light remains the same. It's absolute. Weird, eh?

Einstein made his great leap forward by determining how this happens. He knew that for the speed of light—a value consisting of a measure of distence divided by a measure of duration—to be invarient, something had to give. And this is the paradigm-smashing insight he came to: Time is relative (as is space, but that's another story). Put another way, Einstein realized that each reference frame has its own clock, and these clocks run at different rates. In particular, clocks will slow down under specific conditions. In his Special Theory of Relativity, Einstein outlined how motion, or velocity, influences the measurement of time. In his General Theory of Relativity, he explained how gravity and acceleration also influence the measurement of time.

Surfing the Universe: The Slowing of Clocks

The slowing of clocks has been referred to as the "dilation of time." To dilate means to stretch out. (For reasons I hope will become clear later on, I prefer to refer to the slowing of clocks simply as "the slowing of clocks.") How can a clock slow down? To understand this process it is helpful to know a thing or two about surfing. When I moved to Florida a few years ago, I taught myself to surf. Besides introducing my ears, nose, and throat to a whole slew of saltwater microbes, surfing helped me to gain insight into relativity theory.

There you are, a beginning surfer, standing in chest-deep water, waiting for a wave to come your way. You see a good one approaching, so you slide onto your board and begin paddling. You hope the wave breaks just behind you, and as you feel the whitewater-surge accelerate you and your board, you stand up. As a beginning surfer you head straight to shore, performing, in surfer lingo, what is called a "straight-off Adolph." What is your speed as you catch a wave and head straight to shore? Let's assume the distance is 30 meters. And, for simplicity's sake, let's call the duration "one Kahuna." On your ride to the shore you travel 30 meters in one Kahuna. Each time you catch a broken wave and surf straight to shore—which is referred to as "whitewater" surfing—you travel at the same speed: 30 meters per Kahuna. Look Ma, no hands!

Once you perfect whitewater surfing, you're ready to make the leap to real surfing: green-water surfing. In this case you position yourself out in the water, and for our purposes we'll again say 30 meters from shore, and you wait for a wave. When you see a glassy hump in the water build and build, you flop onto your stomach and start paddling. This time you want to catch the wave just before it breaks. As the building wave reaches your ankles, you give a couple of additional frantic paddles, and hope that you are picked up by the wave. Suddenly you find yourself falling down the face of the wave. And here comes the difficult part. Just as one region of your brain is shouting, "You're falling, you're falling!" another region of your brain, a newly developing region, the surfing lobe, screams, "Dude! Now! Stand up!" And so you do a push up on your board as you fall down the face of the wave. You lean heavily on one arm so as to cause the board to turn away from the beach and toward the unbroken wave surface. You pull your feet beneath you and stand on the moving slab of fiberglass. If you succeed, you find yourself slicing along the face of the wave as the white maw of the break chases you. You zip along the slick surface of green water, not toward the beach, but along it. Of course, the wave still pushes you to the shore. But with this type of surfing you often find you have traveled, say, 40 meters up the beach as the wave pushed you 30 meters to the shore.

Green-water surfing is much more fun than white-water surfing for two reasons: (1) You can carve your board along the face of a wave as you outrun the angry break; (2) You go much faster. How much faster? In the above example, not only did you go 30 meters toward the shore—we'll consider that one vector—but you also progressed 40 meters up the shore, a second vector. Because these vectors meet at a right angle—straight into the shore and along the shore—we can use the trusty Pythagorean theorem, $A^2+B^2=C^2$, to calculate the resultant vector. Distance traveled in this case is 50 meters. How long did it take you? Waves break and move to the shore fairly parallel to the shore (at least for our purposes they do). Thus the duration for the green-water surfer is also one Kahuna. His speed is therefore 50 meters per Kahuna. That's much faster than the beginner's 30 meters per Kahuna.

Now, instead of a surfer, we're going to imagine a photon, a quanta of light, reflecting between two mirrors at the beach. One mirror is 30 meters out from shore, the other runs along the shore. These mirrors are miles long. To create the most basic of clocks, we are simply going to send a photon reflecting back and forth between these two mirrors. Each time the photon hits the mirror on the shore, we'll consider that a "tic." Each time the photon hits the mirror 30 yards out, we'll call that a "toc." What is the photon's speed? In keeping with our surfing example, we'll say 30 meters per Kahuna. Because the speed of light is absolute, that is the speed the photon will always travel.

In his Special Theory of Relativity, Einstein revealed that a clock would slow down when set in motion. Because the speed of light is so very fast, the slowing of clocks is not normally manifest. But in our case, because we have the photon traveling at a more manageable pace, we'll be able to see how this slowdown can occur.

Instead of the photon merely bouncing back and forth between the mirrors, tic-toc, tic-toc, we're going to imagine it traveling diagonally, like a green water surfer. In other words, we're going to push the oscillating photon up the beach. The photon no longer goes back-forth-back-forth. It goes diagonal toward one mirror then diagonal toward the other.

If the photon can only do 30 meters per Kahuna, what's going to happen under this condition? If you imagine a diagonal vector and compare it with the straight-off Adolph (perfectly perpendicular) vector, you could claim that, to the photon, the mirrors are now farther apart. While the perpendicular vector's tip touches the mirror, a

diagonal vector of the same value falls short. In other words, the photon has to travel farther to hit a mirror and "tic" or "toc." Because our photon can never exceed the 30 meters per Kahuna speed limit (unlike the surfer), the "tic-toc" is going to become a "tic… toc… tic… toc." And the faster we push the photon *up* the beach, the farther the photon has to travel to meet a mirror. So the photon-clock slows even more. If the photon were propelled up the beach at its absolute speed, at 30 meters per Kahuna, what would we find?

We would find that the photon would not make any progress toward a mirror. Relative to the mirrors, the photon would, in fact, stand still. All its motion would be along the shore. If you could accelerate a clock to the speed of light it would stand still. Here I'll allow myself to be loose with language and say, at the speed of light, "time" stands still. Why? Because nothing can exceed the speed of light. Any physical process that could serve as a clock cannot be accelerated to light speed because part of the process would produce a vector that, combined with light speed, would exceed light speed.

Besides high velocity, acceleration and gravity will also slow a clock. And indeed, experiments have demonstrated these phenomena: atomic particles take longer to decay when traveling at high velocity; a clock placed at the bottom of Death Valley runs measurably slower than one high in the Rockies.

Now that we've seen how clocks can operate at different rates, we're ready to take a hard look at what relativistic "time travel" really entails.

Larry, Barry, and the McCaughey Septuplets: The Semantics of Time Travel

The best-known example of relativistic time travel involves a set of twins. So we'll also use twins. We'll name them "Larry" and "Barry." Larry gets on a space ship and sets off on an extremely rapid journey through the cosmos. When Larry returns to Earth he discovers that, according to his watch, he has been gone one year. And his body has aged one year (all physical processes can serve as clocks and are thus slowed down). Meanwhile, Barry's watch, and Barry's body, have moved ahead 30 years. The conclusion: Larry has traveled 29 years into the future.

In a nutshell, that is what relativistic time travel is all about.

For two reasons I think this most common example of time travel is misleading. First, people tend to think of the earth as the default, or the true, reference frame. That is why, when Larry returns to Earth, people can say, "Aha, he is in the future." Barry never left the Earth, and his clock reads such-and-such. Which is what matters, right? Wrong. There is no true time. Larry's clock is just as valid as Barry's clock. One could even claim Barry had traveled backward in time according to Larry's clock. But we focus on Barry's clock. We give it precedence. Sure, Barry's clock may be synchronized with many other clocks on earth, but the fact remains that neither Larry nor Barry's clock tells the absolute time. There is no absolute time. In a very real sense, Larry's traveling in time relies upon a human mind concluding, "Larry's watch says one year has gone by, but 30 years have really gone by. Larry is now 'in' the future."

The second reason I believe the twins example, along with the term "time travel," is misleading is because two clocks are needed for time travel to occur. Yet at the end of the story we toss one aside. But there is no time travel without two clocks. That is why we ought to refer to it as traveling in "times." It is only because we designate one clock as telling the true time that we can refer to it as time- (singular) travel. Any relativistic time travel depends upon this switching from the reading of one clock to the reading of another clock. We employ a "sleight of mind," if you will. There is no time travel without thinking of it like this: "x" years have passed according to this x clock, but "the time" is really "y" years because the true clock, the y clock, says so.

Relativistic time travel depends upon a difference between clocks. Or, you might say, time travel exists in the 'relation' between clocks. We'll return to this element a little later.

Consider my own time travel *gedanken* (thought experiment). Remember the McCaughey septuplets—Kenny, Alexis, Natalie, Kelsey, Nathan, Brendon, and Joel? Imagine they have grown up and are all working for NASA—astronauts, each and every one of them. Good job, Mom and Dad! The McCaughey bunch is living aboard a space station consisting of seven interlocking pods. The septuplets synchronize their watches. Then the pods break apart and each goes zooming off in a different direction at a different speed and each encounters different acceleration and gravitational fields. Later (according to the clock in our heads) they reunite. First one returns, then another…and another, etc. When all the pods are back in position, the septuplets have a sibling reunion. There's a cooler full of Tang and re-hydrated franks and beans. Over dinner the McCaugheys discover that each of their clocks reads a different time. And each of them has aged differently. In this case, one in which there are seven distinct "times"—and no default reference frame to be found or readily designated—what can we conclude about what time it is and who traveled in what time?

Actually, we could say a lot of things. We could make many different comparisons between clocks and have every septuplet traveling into the future or past of every other septuplet. We could have Kenny traveling to Alexis' future and to Natalie's past…Kelsey traveling to Kenny's past and to Nathan's future, etc. If we bothered to include all possibilities, the result would be 112 different travels "in time." And all on one family vacation without a triptych from Triple-A.

It must be noted that we couldn't claim any McCaughey had traveled in time until we designate which time was the "true" time. And to determine that, what do we do, take a vote? There is no such single entity as the true time. All of the septuplets' clocks are equally valid, until a human mind decides one is more legitimate than another.

Is "time travel," then, just a play on words? Let's consider what each of the terms means and whether the meaning matches the phenomena in question.

First we'll look at "travel." In everyday usage "travel" means to visit some place and then return. That's traveling. In one sense, you could say relativistic time travel does involve visiting another time. But not really, because you never leave your own time behind. Your own clock—your own reference frame—stays right there with you. You can't leave it behind. You can ignore or re-set your clock, but that's cheating. So, in this sense, time travel doesn't so much involve visiting another place as it does juxtaposing two different places…places in times.

Another way "travel" doesn't fit the phenomenon in question is that the word implies the ability to go home again. Relativity, unfortunately for aspiring time travelers, does not allow clocks to go backward. They only go forward at different rates. So there is no going home again. Thus, relativistic time travel is more like time-emigration. It's a one-way trip. Larry is never going to visit Barry at 30 years, then return to where Barry's clock or his own reads less than when they first reunited. There's no going back. Can you really call that travel? I call it "strike two" against the term "time travel."

What about the word, "time"? Before skimming the surface of the nature of time, and thus the meaning of the word (a topic that has been debated for centuries), I would like to share with you an extremely significant scientific fact. Are you sitting down? The relativistic slowing of time has never been experimentally verified. Never.

Hold on—before you write me off as a loose Fruit Loop lodged between the bag and the box, ask yourself, "Have I made the assumption that 'clock' and 'time' are synonymous?"

There is no doubt that the slowing of clocks has been experimentally verified. In fact, the clocks orbiting the earth in G.P.S. and other satellites have to be regularly set back so they stay synchronized with the slower moving clocks lower down in the earth's gravitational field. But these are clocks. These are real things, things we can see and touch. Can you see or touch time?

You might protest, "Hey, we can't see or touch the earth's magnetic field, but it exists. It takes a compass to show it's there." That's true. But is a clock to time what a compass is to a magnetic field? Does a clock "tell" time as a compass tells the direction of a magnetic field? I would say not. Here is the difference: A magnetic field is the only way to explain why a compass does what it does. But a clock doing what it does can be explained by the workings of a spring and gears, or a battery and a quartz crystal. These workings alone are sufficient to explain why a clock behaves the way it does.

Pine Trees and Philosophies of Time

Beliefs and philosophies about time can be roughly divided into two main categories: substantival and relational.

The substantival, or the "absolute," perspective considers time to be a sort of invisible house the universe lives in. Time is thus substantive, it "stands out." Time exists on its own; it is independent of the workings of the universe. According to this perspective, if there were no objects or events, time would still exist.

Because time, according to the substantival perspective, stands apart from objects and events, existing independently of these, it must be considered a metaphysical construct. There is no way to empirically confirm its existence. And to the extent this time is said to have any causal influence on the workings of the universe, it might also be considered a supernatural agent. For these reasons I believe the skeptical thinker cannot accept the substantival perspective.

According to the relational perspective, time is a way we describe the relations between objects and events. To the relational perspective, where there are no objects and events (such as before the Big Bang), there is no time. You might say time is a tool employed by the human mind.

In my backyard I've got two trees—an oak and a pine. The pine tree is taller. I would say the "pine" of the pine tree is an absolute characteristic, while the "taller" is a relational characteristic. The "pine" characteristic is absolute because it is independent of anything that goes on around it. If the tree floated in the void of space, its pine-ness would still exist. The "taller" characteristic, however, is relational. Without another tree to be compared to, the pine tree cannot be taller. The tree's taller-ness is context-dependent.

The substantival perspective of time lends itself to visualizing time as many rooms. There are the many rooms of the future, the dynamic room of the present, and the many rooms of the past. These rooms are substantive; they exist in some way. And so time is coupled with space. How could something exist if it didn't exist in space? Each time could be seen as a room in the great house of eternity. With this perspective it is easy to imagine time travel. To travel in time would be simple—all you have to do is move to a different room.

While traveling through a house to a specific room may make sense (i.e., visiting is an absolute characteristic), traveling to a relation, or a relational characteristic, does not. How does a person visit a relation between events?

As mentioned earlier, two clocks are needed for time travel to occur. The time traveler doesn't travel in time according to one single clock. There is always a juxtaposition of clocks. Does time travel arise only in a relation between events? Is this relation something real, something that exists in the universe? Or is this relation, and time travel itself, fully dependent upon the workings of a mind?

In my own, perhaps overly simplistic, way of looking at it, time consists of some designated periodic change that is used to mark, measure, and coordinate other change or changes. And relativity theory reveals that rates of fundamental changes vary due to high velocity or to gravity or to acceleration. So rather than having traveled to Barry's time, Larry has instead experienced a different rate of change.

The Windmill and the Watch: A Final Time Puzzle

Consider this parlor trick: On each of your wrists you wear a wristwatch accurate to ten to the minus twenty seconds. At this time-scale, relativistic effects due to human motion are readily measurable. Clocks today are accurate only to ten to the minus fourteen seconds. And they're much too big to wear on a wrist. But say you did have two such watches. You could synchronize your watches and then windmill one arm around and around while keeping the other stationary. The windmilled watch would be subject to acceleration—constantly changing direction—and acceleration causes clocks to slow down. With your super-sensitive watches you wouldn't need to windmill your arm very long before, upon stopping the movement and allowing the blood to rush back out of your hand, you discover your wristwatches now read two different times. It would be fully in line with contemporary thinking for you to conclude that your windmilled watch and your windmilled hand had traveled into the future. The watch on that wrist shows less time. Wow, you made one of your hands travel in time. In fact, you could perform the experiment right now, in the privacy of your home or office. Just because the watch you own isn't sensitive enough to measure the difference, the difference would be there, hidden in the tiniest fraction of a second. You can send one of your hands into the future. Time travel is easy. Anyone can do it.

But has one of your hands really traveled to the future? Or has it traveled to the other hand's time? Or has it only traveled in your mind? Isn't it true that your windmilled hand is still right there, in its very own reference frame?

Go ahead, try it right now. Stand up and send one of your hands wind-milling into the future. Then, ponder this: If you didn't compare one wristwatch to another, how much sense would it make to claim that one of your hands had traveled in time? ▼