

# Time for a Change

## The Instantaneous, Present and the Existence of Time

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[25, August, 2008]

Take it moment by moment, and you will find that we are all, as I've said before, bugs in amber.

Kurt Vonnegut [1922-2007], *Slaughterhouse-Five*

Puzzlement over the nature of time, and the desire to understand it, is as old as human thought itself. Of all the things that shape existence, both ours as people, and the universe as a whole, time – or at least, change – is probably the most central. It has also proved one of the most elusive. Even the late Richard Feynman seems to have been at a loss to explain it. In his acclaimed lectures at the California Institute of Technology during the 1960s, he masterfully described how Albert Einstein changed the prevailing view of time and space as distinct things, into a combined and inseparable space-time. Yet, when Feynman pondered what time actually was, he did not really have an answer. “We physicists work with it every day,” he said, “but don’t ask me what it is. It’s just too difficult to think about.” The noted British mathematician and philosopher, Alfred North Whitehead, once commented, “It is impossible to mediate on time, without an overwhelming emotion at the limitations of human intelligence,” while Adam Mendilow wrote, “Nothing puzzles me more than time and space, and yet nothing puzzles me less, for I never think about them.”

Although through such theories as special and general relativity, and the second law of thermodynamics, our understanding of time has come a long way since the Greek philosophers originally pondered its nature two and a half thousand-years ago, in many ways it remains just as mysterious. The question of time’s actual existence, and the puzzle of time and its relationship to quantum mechanics and quantum gravity, are striking examples of this. If we look back over history, however, we often see that when a breakthrough has been made in our understanding of time, it has also usually led to a revolutionary new theory in physics and a dramatic change in the way we view the world. I have little doubt this will be just as true in the years to come.

### Back to the Future: Zeno’s Paradoxes

One of the oldest and most famous problems involving time are Zeno’s paradoxes, originally conceived by the Greek philosopher, Zeno of Elea, around 450 BC. They are so well known that I will avoid going over them here.<sup>2</sup> I will, however, explain the historically accepted solutions to the three most famous ones: the Arrow, The Dichotomy, and Achilles and the Tortoise.

The most ordinary things are to philosophy a source of insoluble puzzles. With infinite ingenuity it constructs a concept of space or time and then finds it absolutely impossible that there be objects in this space or that processes occur during this time.

Ludwig Boltzmann

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<sup>2</sup> For a summary of Zeno’s paradoxes, see <http://www.iep.utm.edu/z/zenoelea.htm#HI>

Of Zeno's paradoxes, the Arrow is typically regarded as a different type of problem to the others – thus also requiring a different type of solution. Over the past 300 years, it has usually been claimed that the Arrow paradox is resolved through calculus, the use of continuous functions, and the idea of “limit.” Although Isaac Newton and Gottfried Leibniz were the first to introduce these methods, it was not until the 19<sup>th</sup> century that a reasonably rigorous foundation to do this was provided with the “epsilon-delta” definition of limit by the mathematicians Augustin-Louis Cauchy and Karl Weierstrass. The essence of what they did was to dispense with infinitesimal-quantities and the infinite altogether, and instead think in terms of relationships between small, but finite, quantities that can potentially be made arbitrarily small by taking them to an unreachable “limit.”

A good way to picture this idea is to consider a polygon inside a circle, with the circle representing the limit of the polygon's sides. If the number of polygon's sides is increased, the lengths of the sides decrease, and the polygon gets closer and closer to becoming a circle and to reaching the limit. As it will always still have sides, the polygon can never actually get to be the circle, but it can get arbitrarily close, so for all practical purposes, it is said that it might as well *be* the circle.

In this example, the polygon is analogous to an object's motion and velocity, and the circle, to the limit of the object's velocity at an instant. Thus, when applied to Zeno's Arrow paradox, this means that, although the limit of the arrow's velocity at the instant is never actually reached, as the time interval approaches zero (roughly analogous to the length of the polygon's sides), the arrow can be taken arbitrarily close to it, so for practical purposes, the arrow is said to have a non-zero velocity at the instant, and thus, not to be motionless. Furthermore, although not actually moving *during* the instant, if the arrow's trajectory is traced out, it can be said to be in motion because it can be seen to occupy different locations at different times. As the arrow could be said to have an infinite-number of different positions at different times within this context, it is also sometimes claimed that the arrow is in motion at *all* instants in time (an infinite number of them).

The paradoxes of Achilles and the Tortoise and the Dichotomy, on the other hand, have generally been thought to be solved by the summing of an infinite series, a mathematical technique developed by Cauchy, Weierstrass, and the German mathematician, Richard Dedekind. In relation to the paradoxes, this means the summing of an infinite series of progressively small time intervals and distances, so that the time taken for Achilles to reach his goal and overtake the Tortoise, or to traverse the said distance in the Dichotomy, is, in fact, finite. The faulty logic in Zeno's argument is seen to be the assumption that the sum of an infinite number of terms is always infinite, when in fact, an infinite sum, for instance,  $1 + 1/2 + 1/4 + 1/8 + 1/16 + 1/32 + \dots$ , can be mathematically manipulated to be shown equal to a finite number, or in this case, equal to 2. Therefore, Zeno's infinitely many subdivisions of any distance to be traversed, can be mathematically reassembled to give the desired finite answer, and the body in apparent motion in the paradoxes said to have reached its said impossible goal.

By the end of the 20<sup>th</sup> century, people could generally be divided into two camps about Zeno's paradoxes. Those who did not think that they represented any real problem and were happy with how calculus was thought to address them, and those who believed calculus missed the whole point of the paradoxes and that they had not yet been resolved. As the first group was by far the largest, however, Zeno's paradoxes were generally considered to be a topic purely restricted to the history of mathematics, physics and philosophy; something that was settled long ago.

## No Instant In Time

Let anyone try, I will not say to arrest, but to notice or attend to, the present-moment of time. One of the most baffling experiences occurs. Where is it, this present? It has melted in our grasp, fled ere we could touch it, gone in the instant of becoming.

William James

In 2003, I published a paper that put forward a solution to Zeno's paradoxes. The paper had initially been written about four years before this, but did not appear until this time. I realized that Zeno's paradoxes assumed, as did physics in general, the existence of an instant in time at which a body in motion could be said to be in an exactly determined or instantaneous position. If a moving object could be said to have a determined position relative to something else at an instant, as is the very nature of this ethereal notion – a static “snap-shot” of a physical process – the object would necessarily be frozen still at that instant and could not be in motion at all. That is, it is that its position is constantly changing that enables a body to be in motion in the first place. By assuming that an object could be said to be in an exact position at an instant – and then dissecting its motion as such – the paradox was created. Thus, the solution to the paradoxes lay in recognizing these faulty assumptions, and as such, that motion could also not be fractionally dissected in this way. This applied to the paradoxes of Achilles and the Tortoise, the Dichotomy, its variations, as well as to the Arrow. As I would like to go into the paradoxes in a little more depth than this, however, let's have a closer look at them.

How wonderful that we have met with a paradox. Now we have some hope of making progress.

Niels Bohr

The way in which calculus was thought to solve the paradoxes of Achilles and the Tortoise and the Dichotomy through the summation of an infinite series, certainly provided the correct answer in a strictly mathematical sense by giving up the desired finite number at the end of calculation. It was dependent, however, on an object in motion having an exact relative position at each given instant in time. Moreover, the summation of an infinite series here worked as a helpful mathematical tool to get rid of the infinities, but it did not actually resolve the paradoxes and show how the body's motion was possible. In this context, it was little more than “rounding up.”

The same fault applied to the Arrow paradox's proposed solution by calculus, as the “limit” of the arrow's velocity at the instant is never *actually* reached; strictly speaking, the arrow does not have a velocity at the instant. It cannot, as by definition, an instant has no duration, so the arrow cannot have a velocity at an instant if there is no interval of time during which it could cover a distance. Indeed, to say that it could have one, was like saying that a stationary body could at the same time be moving, or that a multi-sided polygon could also *be* a circle. Furthermore, as a continuous function is a static and indivisible mathematical entity, by invoking this model, people were essentially agreeing that motion did not exist and was some sort of strange subjective illusion.

Mathematics are well and good but nature keeps dragging us around by the nose.

Albert Einstein

What was not realized was that, in all of the paradoxes, and in all of the proposed solutions to them by calculus, it was taken for granted that a moving body had a determined relative position at any given instant in time. As explained earlier, this is not the case. There is no such thing as an instant in time, and regardless of how small the time interval or slowly a body is moving, its position is constantly changing and undetermined. If its position were not constantly changing, it could not be in motion. When this realization is applied to the Arrow paradox, one also recognizes that there is not an instant in time underlying the arrow's motion at which its volume would occupy just "one block of space," and because its position is constantly changing and undetermined, the arrow is never static and motionless.

The paradoxes of Achilles and the Tortoise and the Dichotomy are resolved by this same realization. When the moving body's associated position and time values are fractionally dissected in the paradoxes, an infinite regression can then be mathematically induced and the idea of motion shown to yield paradox, as such values are not representative of instants in times at which the body is actually in each exact position, but rather, of intervals of time during which the body is passing through specified intervals of distance. For example, a time value of 1 second (which indicates the time interval of 1 and 1.99999..., seconds, and not an "instant"), is not indicative of a time at which a body's position might be determined while in motion, but rather, if measured accurately, is a representation of an interval in time during which the body is passing through a particular distance interval, say 1 meter (which indicates the distance interval of 1 and 1.99999..., meters, and not a precise "spatial point.") Incidentally, note that a spatial point is perfectly analogous to an instant, with the difference just being that it has no spatial extent, rather than no duration. As such, if instants or points in time have no physical meaning, and an object in relative motion does not have an exact relative spatial position at one, points in space have no physical meaning either.

The fact that an opinion has been widely held is no evidence whatever that it is not utterly absurd; indeed in view of the silliness of the majority of mankind, a widespread belief is more likely to be foolish than sensible.

Bertrand Russell

At the time of writing, I think it would be representative to say that most people still believe that Zeno's paradoxes are resolved by calculus. Mathematics and philosophy students are taught this in university, while the vast majority of scholarly and popular texts on the topic present the same. The said calculus solutions to Zeno's paradoxes represent a tremendous amount of ink, paper and web-space. Though Nature is the opposite, it is perhaps fitting that, 2500 years after he put them forward, Zeno's paradoxes still seem especially resistant to change.

### **Instantaneous Magnitudes**

An implication of the conclusion that instants in time do not exist also seems to go against intuition. Not only does an object in motion not have a determined relative position, but all physical magnitudes are not determined at an instant either. If relative position is not determined at an instant, neither is velocity (which is the rate of change in relative position with respect to time). If velocity is not determined, neither is acceleration (which is the rate of change in velocity with respect to time), momentum (which is velocity multiplied by mass), and through the subsequent derivation of the remainder of the equations of physics, neither is any other physical magnitude,

including mass, energy, gravity, and indeed, the geometric framework of space-time itself. Importantly, however, this universal indeterminacy in precise physical magnitude is not associated with the preciseness of the measurement, or the result of quantum uncertainty. In exactly the same way that an object in motion does not have a determined relative position because its position is constantly changing, and the idea of its motion having a “limit” at an instant is faulty, instantaneous magnitudes do not exist either.

There is nothing permanent except change – Heraclitus

The only situation in which a magnitude would be precisely determined is if there were an instant in time underlying physical processes in Nature, and as a consequence, a system was frozen static at that instant. In such a system, an indivisible mathematical time value, say 2 seconds, would correctly represent an instant in time, rather than an interval in time. Fortunately this is not the case, for if it were, this static frame would include the entire universe, and the cosmos’ evolution would not be possible. Thankfully, it seems that Nature has wisely traded certainty for continuity, with there being a necessary trade off of all determined physical magnitudes at a particular time, for their continuity over time.

### **No Time, No Space**

The realization that there was no such thing as an instant in time, and that an object in relative motion did not have a determined relative position, had some further implications. Perhaps the most obvious one related to the nature of time itself. If there is no such thing as an instant in time, I also realized that there could be no “flow” or passage of time, for without a continuous progression through indivisible instants over an extended duration, there could be no physical progression or flow. In other words, there was nothing *there*, no temporal stepping-stone, for which time could possibly use to progress. Kind of similar to how an invisible ether was once assumed to permeate throughout the entire universe, Newton’s invisible river of time, assumed by many to enable motion and change as it proceeded, could not exist either. It had no water. Although we certainly *feel* as though we are swimming along with it, we are actually high and dry. Further, the same could be said for the existence of space, due to the lack of spatial points.

What this means is that, not only is time and space not absolute, with judgements of position in space and “nows” in time being relative (the time aspect being shown by relativity), but there are no such things as relative position, “nows” in time, nor things called “time” or “space,” out there, physically existing independently of us, at all. This may seem counter-intuitive, for in respect to time, it might suggest that if it were not a fundamental physical entity, the entire universe would be frozen static and motionless at one particular instant as though stuck on pause on a movie-screen. However, if the universe were frozen static in such a manner, this would constitute an instant of time – time *would* be a physical thing, rather than not. Indeed, so presumably would space, as such an instant would represent the same thing (i.e. a static block of “something,” somehow different from matter, filling the entire universe), while also having the same affect on continuity. Thus, it seems that it is actually due to nature’s exclusion of time and space as fundamental physical things, that motion and change are possible, and that intervals of time and space are able to “represented” by clocks and rulers in the first place.

The idea that time might not flow and that the passage of time may be an illusion, is clearly not at all a new one, and from the time of the ancient Greeks, a number of different arguments and observations have been put forward supporting the notion. The lack of differentiation between past, present and future in relativity is probably the most striking of these. However, as the idea of a flowing time is the intuitive view – and indeed, it is no doubt is extricably tied up with our conscious perceptions – its existence has continued to be assumed by many. With, perhaps, a perceived lack of a truly fundamental argument against time’s passage, some have also seemed happy to sit on the fence about the issue. That many people seem to assume that time and space as they enter general relativity are literally curved by the presence of matter and energy, as if they were actual physical “things” (rather than just interval in time as represented by a clock, and interval in space – length, width and height – as represented by a ruler, being dilated by them, and, among other things, the non-Euclidean geometry of general relativity providing an effective way of modeling the motion of a body within this context), would no doubt not have helped much either.

Indeed, the absence of instants in time and spatial points spells bad news not only for time and space, but for space-time as well. As they assume instants and spatial points in order to bound and determine their contributing temporal and spatial values as intervals, time and spatial coordinates in special and general relativity also have no physical reality. This then means that the same can also be said for space-time points (which consist of one time and three spatial coordinates), space-time intervals (the distance between two space-time points on a space-time manifold), and as such, the space-time continuum itself.

Space-time does not claim-existence in its own right, but only as a structural quality of the [gravitational] field.

Albert Einstein

In relation to space-time having no physical existence, this is far from a revelation. Einstein himself held this view, and often appears to have been careful to make a note of it. It just seems that this point was lost on a number of subsequent physicists and mathematicians, seemingly unable to make the same differentiation and recognize the limits of applicability of Einstein’s model of space and time. As the reality of space-time would have been seen by many physicists and mathematicians as being more of a philosophical question – a distraction to the real business of solving equations – some would also have not been overly concerned with such an issue. Theories that assume the physical existence of space-time – for example, relativistic time-travel, imaginary time, and arguably, extra space-time dimensions – would bare witness to this.

Paradoxically, even physicists who held that time or space-time did not exist, seem to have failed to realize that by assuming that events were underpinned by instants and “nows”, they were inadvertently saying that time and space-time *did* exist. Perhaps the most striking example of this is the Oxford physicist, Julian Barbour, who made instants and “nows” a central feature of what he saw as being a completely timeless view of the universe. However, the same can also just be said for physicists who assumed that Newtonian mechanics, special and general relativity, or quantum theory (in the context of formalism like Schrödinger’s equation), provided an accurate description of Nature, in the sense of assuming that an instant or a space-time event, both static entities, had direct physical correspondence. The same can again be said for the positing of definite positions in Bohmian mechanics – a version of quantum theory named after its principle developer, David Bohm. Pertinently, because the theory necessarily requires the existence of instants and spatial points to bound and

determine their respective values as minimum, indivisible intervals, time and space can also not be quantized, while, because there is nothing *there* to travel through, time-travel does not appear to be possible either.

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 together. It is a notion sometimes referred to as block time.

Paul Davies

If instants or “nows” do not exist, what of the past and future? General relativity tells us that all events in the universe, past, present and future, are all mixed up together, sharing equal temporal status. In relation to time, nothing actually “happens” at all. However, this “block” view of time seems to be very much at odds with how we as people seem to experience the world. Indeed, a number of physicists and philosophers view this seeming incompatibility as representing a real problem because, with all events already laid out together in time, they do not see that this allows for motion and change. Others just accept that motion and change are illusions.

However, I think that neither is the case. As long as one recognizes that, like instants and spatial points, space-time points and intervals do not exist either, motion can still take place with such a “block” view. One must just solely focus on the motion and matter in the universe – and except for the interval as represented by a clock being used as the reference – completely ignore and forget about time, instants, the present, space-time points, and the past and future, making no reference to them. If this is done, any potential problem disappears, and motion and change can be seen to be entirely possible in a timeless “block” universe.

Before continuing, I think that it could be a good idea to briefly reiterate some things. If anyone is possibly a little confused over the issue of time and space’s existence, hopefully this may help. Time, space, and space-time too, as commonly conceived as actual physical things, do not exist. Physical continuity (i.e. the capability for events to be continuous), and as such, motion and change, do exist, however, and this in turn enables the hands of a clock to rotate, and thus, one to indicate an interval of time. It also enables a progression along the length of a ruler, and one to indicate an interval of length or space. This then in turn also provides intervals to use for space-time coordinates and to derive a space-time manifold in relativity. As such, because the presence of physical continuity enables one to indicate intervals with a clock or ruler, interval of time and space, and consequently, space-time too, still have much meaning in physics. I think it is also important to note that, strictly speaking, clocks and rulers do not actually “measure” intervals of time and space. As they do not refer to anything except themselves, they themselves “represent” them. That is, there is no flow of time, and it is physical continuity which is basic and fundamental, not interval, so there is nothing *there* to measure.

### **Putting it in Perspective**

I have learned throughout my life as a composer chiefly through my mistakes and pursuits of false assumptions, not by my exposure to founts of wisdom and knowledge.

Igor Stravinsky

We have seen that much of physics assumes the existence of instants of time. Although reality might disagree, in most cases this is harmless. With or without

instants, the equations of physics still work exactly the same and the numbers that they provide remain just as useful. The real problem arises when these faulty assumptions are not recognized and then lead to contradiction and paradox (as with Zeno's), or they are unknowingly built into theories whose possible validity is dependent on them (as with time and space's quantization). Naturally, the same pothole lays in wait for theories that assume the existence of time or space-time (i.e. time-travel, imaginary time, etc). Although I must admit that I find it very surprising that the existence of instants and instantaneous magnitudes seem to have always just been assumed, I think there are at least three good reasons for how this may have happened. The first is attributable to the nature of mathematics, as, when applied to physics, it implies that functions and mathematical values are indicative of instants and instantaneous values. The same can be said for our assumptions regarding the use of "limits" in physics. Indeed, a similar thing can be said for a photograph, with people often assuming that a picture is representative of an instant of time, rather than a small interval.

Secondly, I believe that we actually *think* within the context of an instant and present moment in time and project it onto the world around us. For example, if you think of a car driving down the road and are asked if it has a determined relative position to the road, you can mentally picture it having one, so you assume that it does. Indeed, you can only mentally picture the moving car in the context of static frames or instants.

Lastly, I think that people just assumed such things were settled and beyond reproach. Their validity was not thought to be in question. This also probably represents the work's greatest obstacle, as a number of people seem to find it very difficult to believe that we could have got it wrong, especially considering the amount of water that has passed under the bridge. It just seems a bit too unlikely. Given my lack of formal qualification, my involvement probably does not help this perception.

The most common criticism of the work has been that it has no mathematical model to back it up. This has also surprised me. Much of the point of the work was to show that calculus has its limitations when trying to accurately represent Nature – something dynamic – in the sense that it freezes everything upon being applied, rendering it a statue. To try to employ calculus itself to show this would be impossible; akin to trying to use sound to explain why sound cannot be used to describe taste.

Before finishing, I think I should also emphasize that, in relation to physics, the value of the work is limited. Other than that motion and physical continuity should be possible, and that time and space are not quantized, it is not really able to make any verifiable predictions, so a good portion of it is philosophy of physics, rather than physics. That is, we already know that physical continuity is possible, as my being able to write this demonstrates, so predicting that it should be is a bit redundant! Perhaps trying to devise an experiment to prove the non-existence of instants of time, time or space, when none of them will ever show up in an experiment, is also a bit redundant – not to mention slightly paradoxical. As such, instead of predicting the outcome of experiment, the work's value lays in giving a better understanding and clarification of some things, ruling others out, as well as in resolving Zeno's paradoxes. At the same time, however, I do think that some revolutionary work in quantum mechanics and quantum gravity could potentially stem from it. Time, that which is represented by a clock, will tell. Whatever the case, time and space are in serious trouble, and although the Emperor has a clock, a ruler, and he is thankfully able to run and hide, he most definitely has no clothes.

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In order to meet the essay word limit, I was unable to include some material that I would have really preferred to. This included discussion of (1) the problem of time in quantum gravity, (2) the non-existence of instants, (3) the solution to William James' version of the dichotomy paradox, (4) others who have been on the right track with Zeno's paradoxes, (5) the non-existence of interval, and (6) why time and space cannot be quantised. The omitted material, along with references, may be found at [www.peterlynds.net.nz/fqxiessaynotes.pdf](http://www.peterlynds.net.nz/fqxiessaynotes.pdf)