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Space and Time

This article discusses the following issues about space and time: whether they are absolute or relative, whether they depend on minds, what their topological and metrical structures may be, McTaggart's argument against the reality of time, the ensuing split between static and dynamic theories of time, problems with presentism, and the possibility of time travel. Our opening questions are posed in the following query from Kant:

What, then, are space and time? Are they real existences? Are they only determinations or relations of things, yet such as would belong to things even if they were not intuited? Or are space and time such that they belong only to the form of intuition, and therefore to the subjective constitution of our mind, apart from which they could not be ascribed to anything whatsoever? (A23/B37)

ABSOLUTE OR RELATIVE?

Newton regarded space as a real existence—a vast aetherial container without walls, in which everything else that exists lives and moves and has its being. Leibniz believed to the contrary that space is not a genuine entity, but a mere *façon de parler*; he held that all talk of space is replaceable by talk of material things and their relations to one another. For example, to say that a thing has “changed its place” is merely to say that it has changed its distance or direction from some other thing chosen as a reference object.

This is the issue that divides partisans of absolute or substantival theories of space on the one hand from defenders of relative or relational theories on the other.

To test his or her allegiance on this issue, the reader should answer the following question: if the only material thing in existence were a single particle, would it make sense to say that it is moving? Leibniz would say no, since motion for him consists in change of relations (e.g., of distance) among two or more material things. Newton would say yes, since even in the absence of other material things, the particle could be moving from one cell to another of space itself.

Newton argued for the existence of substantival space with a famous thought experiment. Imagine a bucket suspended from a rope and filled with water. The rope is twisted and allowed to unwind, causing the bucket to spin. At first the bucket moves relative to the water, the water not yet having begun to partake of the bucket's motion, but eventually friction causes the water to rotate as well, and indeed to "catch up" with the bucket so that there is no longer any relative motion between water and bucket. By the time this happens, something else happens as well: the surface of the water has become concave, the water edging up the sides of the bucket. This is explained in Newtonian mechanics as a centrifugal-force effect, similar to what happens when amusement park riders are pinned to the side of a rotating bottomless drum. Newton's argument now proceeds as follows:

1. There is a time at which the water displays centrifugal-force effects, but is not moving relative to the bucket—or any other material thing. (Why not relative to the ceiling, you ask? That is why the experiment is a thought experiment: we are to imagine it performed in a universe with no objects besides bucket, water, and rope.)

2. All centrifugal-force effects are induced by rotational motion
3. Therefore, there is a time at which the water is moving, but not relative to any material thing (from 1 and 2).
4. Motion that is not relative to any material thing is absolute motion, that is, motion with respect to space itself.
5. Therefore, the water is moving with respect to space itself (from 3 and 4)—which must therefore exist.

Newton thus argues that accelerated motion (the water's constant change of direction) reveals itself in its effects and proves the existence of space, the existence of which then grounds absolute *uniform* (nonaccelerated) motions, even though the latter do not manifest themselves

Berkeley and Leibniz objected to the conclusion of Newton's argument, but without making clear which premise they thought wrong. Mach objected to premise 1, claiming that we simply do not know how the water would behave in a universe devoid of ceiling and stars (as though no physicist ever extrapolated his laws to hypothetical situations, such as frictionless planes!). A generally overlooked response challenges premise 4: perhaps motion is *really* absolute, that is, not a change in relation to anything else at all, be it matter or space. The possibility of this last response shows that we should separate two issues that can be posed using the "absolute vs. relative" formula: is space a substance or a system of relations, and are motion, size, and various other spatial commodities absolute (intrinsic) or relational?

Leibniz argued that space is a pseudo-entity because its existence would generate distinctions without a difference or, more precisely, exceptions to his principle of the

Identity of Indiscernibles. Let w and w' be two universes just alike in how all material things are related to one another, but differing in the alleged respect that in w' the entire material cosmos has been moved six miles to the east or rotated through some angle.

Leibniz's argument then proceeds as follows:

1. If there were such a thing as substantival space, w would be distinct from w' .
2. But w and w' are indiscernible—they share all their properties.
3. Things that are indiscernible are identical. Putting it the other way around, any two distinct things must differ in at least one property.
4. Hence, $w = w'$ after all (from 2 and 3).
5. Therefore, there is no such thing as substantival space (from 1 and 4).

To evaluate this argument, we need to distinguish two kinds of properties. A property is *pure* if its being exemplified does not depend on the existence of any specific individual and *impure* otherwise. Examples of pure properties are being red (which is pure and intrinsic) and being next to something red (pure and relational); examples of impure properties are being Fred (impure and intrinsic) and being married to Fred (impure and relational). When Leibniz affirms premise 2, he must mean that w and w' differ in no pure property, for Newtonians could certainly maintain that w and w' are distinguished by the fact that w is such that part of the cosmos occupies cell 233 (an impure property), whereas in w' , cell 233 is empty. But that means when we get to premise 3, Leibniz must advance his Identity of Indiscernibles principle in the following form: any two things must differ in at least one *pure* property (and not merely in such properties as being identical with *this thing*). Leibniz no doubt did wish to affirm the principle in the required form, but if so, it is open to counterexamples. Is it not

conceivable that there be two spheres the same in color, shape, composition, and every other pure property you care to think of?

The substantial vs. relational issue carries over to time. For Newton, time “flows equably without regard to anything external;” for Leibniz, time is nothing over and above the sequence of events said to be in time. Newton (but not Leibniz) can make sense of the idea that the entire history of the world (comprising the same events as now) might have begun earlier than it did.

REAL OR IDEAL?

Another issue about space and time is whether they are ideal, that is, dependent for their existence on minds. The most famous idealist about space and time in western thought is Kant. Kant began his intellectual career as a Leibnizian, but was briefly converted to Newton’s view by considerations about “incongruent counterparts”—objects that come in mirror image forms, like left and right human hands. Kant thought the difference between incongruent counterparts could not be explicated using only relationist resources, but had to consist in the differing relations of the objects to space itself. By the time he wrote the *Critique of Pure Reason*, however, Kant had come around to the third of the positions in the quotation above: space and time are merely “forms of intuition,” that is, ways in which human beings order and arrange the things they perceive; they are not features of things in themselves, or things as they exist outside the mind.

A characteristically Kantian reason for believing that space is ideal is that no other hypothesis accounts for our knowledge of geometry. Kant thought that geometry was a

body of synthetic and *a priori* truth—*a priori* in that it is known in advance of experience, yet synthetic in that it is not validated just by logic or the meanings of our concepts. How can that be? How can we know even before we encounter them that cubes on Mars will have 12 edges? Kant's answer is that (i) our form of intuition makes us incapable of intuiting (perceiving or imagining) any cubes that do not have 12 edges and (ii) as prescribed by idealism, no cubes or spatial objects exist anywhere except those that satisfy the conditions of our intuiting them. Thus all cubes everywhere have 12 edges and the other properties imposed on them by our Euclidean form of intuition.

Kant thought the ideality of space and time was further confirmed by the antinomies—pairs of opposed propositions in which one or the other must be true if space and time exist outside the mind, but both of which are impossible. For example, does the world have a beginning in time, or is it infinite in its past duration? If things in time were things in themselves, one of these alternatives would have to be true, yet both of them boggle the mind. *No beginning* would mean an infinity of events already elapsed, which Kant thought impossible because it would involve a “completed infinity.” (Think of Wittgenstein's example of the man we find saying, “. . . , -5, -4, -3, -2, -1; whew! I just finished counting through all the negative integers.”) *A beginning* would mean an event for which there could not possibly be a sufficient reason—a blow to rationalist aspirations, if not the outright impossibility Kant seemed to think it was. Kant's solution was to hold that past events exist only in present or future memories or other evidence of them (for example, yet-to-be-perceived cosmic radiation). He thought this opened the possibility that the world's history is *potentially* infinite—always extendable further into the past through our future discoveries—but neither actually finite nor actually infinite.

STRUCTURAL QUESTIONS

The next group of questions about space and time (or spacetime, in the Minkowskian melding of them) concerns their (or its) metrical and topological structure. Are space and time infinitely divisible, or are there smallest units? (Zeno's paradoxes of motion are sometimes seen as set up so that the first two apply if space and time are infinitely divisible and the second two if space and time are quantized.) Does space obey the laws of Euclidean geometry or those of one of the non-Euclidean geometries known to be consistent since the 19th century? How many dimensions does space have? Could time have a beginning or an end? Must time be unilinear, or might it branch into multiple paths or close back upon itself in a loop?

The dimensionality of space is representative of such questions. We all know about three dimensions of space—a line possesses one dimension, a plane two, and a solid three. What would it mean for space to have a fourth dimension? (We are talking now of a fourth *spatial* dimension, not time, even though time is sometimes considered as a fourth dimension.) Galileo offered one criterion: to say that space has n dimensions is to say that n mutually perpendicular lines (but no more) can meet in a single point. If our space were four-dimensional, a line could enter the corner of my desktop at right angles to each of its three edges. Poincaré offered another criterion: points are zero-dimensional, and an entity is n -dimensional iff n is the lowest number such that any two points of the entity may be separated from each other by an entity of $n - 1$ dimensions. Thus, a line has one dimension, because any two points of it can be separated from each other by an intervening entity of zero dimensions (another point); a plane has two

dimensions, because any two points within it may be separated by a circle enclosing one of them or a line running all the way across the plane between them; and so on. It is a consequence of this criterion that in a four-dimensional space, a two-dimensional entity would not suffice to separate one point from another. Thus a spherical shell enclosing point A but not point B would not suffice to separate A from B—you could get from A to B without penetrating the shell.

Such things defy visualization in a way that makes some people want to declare them impossible. Those so inclined should read E.A. Abbott's Victorian classic *Flatland*, in which the author describes a world of two-dimensional beings who are incapable of rising out of their plane or visualizing anything beyond it. A Flatlander may be imprisoned simply by enclosing him within a circle or a polygon. Could a Flatlander but jump over the walls of his prison, he would be free, but he is incapable even of conceiving such a motion—as we are of any path from the interior to the exterior of a spherical shell that does not pass through the shell. The exhortation “Upwards, not northwards!” falls on the Flatlander's ears as nonsense. Abbott's intent, of course, is to soften us up for the possibility that our own resistance to a fourth dimension may be as provincial as that of the Flatlanders to a third.

Questions about the structure of space and time give rise to meta-questions about proper jurisdiction—who is to answer them, and how? A traditional view is that space and time necessarily possess whatever structure they do, and that it ought to be ascertainable *a priori* what this structure is. Kant, for example, certainly believed that space is necessarily three-dimensional and Euclidean. The prevalent contemporary view is that space and time have their structures contingently, and that it is only through the

best science of the day that we can reach any reasonable opinion concerning what these structures are. This view was given impetus by Einstein's use of a non-Euclidean geometry in conjunction with the General Theory of Relativity to explain gravitation; it is further exemplified in the work of those physicists in search of a "theory of everything" who posit a space of eleven dimensions.

A view that lies between the traditional and the contemporary views is the conventionalism of Poincaré. Poincaré thought that all the empirical data accommodated by non-Euclidean geometry plus standard physical theory could equally well be accommodated by Euclidean geometry together with non-standard physical theory. For example, measurements apparently indicating that the ratio of circles to their diameters does not have the familiar value of π could be accommodated by a non-Euclidean geometry in which this ratio is indeed other than π , but they could also be accommodated by positing a heat gradient that causes our yardsticks to expand when laid along the diameter though not when laid along the circumference. We could thus always choose to describe our world in Euclidean terms by complicating our physics. This position is at odds with a hardy empiricism, in so far as it denies that empirical results can settle the structure of space, but it is also at odds with an ambitious *a priorism*, in so far as it denies that decisions in favor of Euclid are determinations of independent fact.

QUESTIONS ABOUT TIME

For issues specifically about time, the best point of departure is McTaggart's famous argument of 1908 that time is unreal. Though few have accepted the conclusion of this

argument, nearly all students of time have taken over the distinctions McTaggart employed in formulating it.

McTaggart's fundamental distinction is between the A-series and the B-series. An A-series is a series of events or moments possessing the characteristics of being past (in varying degrees), present, or future; call these the A-characteristics. The B-series is a series of events or moments standing in the relations of earlier-than, later-than, and simultaneous with; call these the B-relations. The chief difference McTaggart notes between the A-characteristics and the B-relations is that the former are transient while the latter are permanent: "If M is ever earlier than N, it is always earlier. But an event, which is now present, was future, and will be past" (LePoidevin, p. 24). In the ordinary way of thinking about time, McTaggart believes, an event becomes increasingly less future, is momentarily present, and then slides ever farther into the past. Yet all the while its B-relations to other events (e.g., its following the Battle of Waterloo and preceding the first landing on the moon) are fixed.

McTaggart's overall argument against the reality of time may be stated quite briefly: (I) time essentially involves an A-series; (II) any A series involves a contradiction; therefore, (III) therefore, time is unreal. Behind each main premise is a subsidiary argument. The argument behind premise I is this:

1. There can be no time without change.
2. There can be no change without an A-series.
3. Therefore, there can be no time without an A-series.

Both premises in this argument have been the subject of interesting debate, but our focus here will be on the argument behind main premise II, which runs thus:

1. The A-characteristics are mutually incompatible, yet
2. Every event in any A-series must have all of them, so
3. Any A-series involves a contradiction.

McTaggart immediately anticipates an objection the reader will have to premise 2: it is not true that any event must have all the A characteristics at once, but only that it must have them successively. An event that is now present is not *also* past and future; rather, it *was* future and *will* be past. In reply, McTaggart claims that this attempt to avoid the contradiction he alleges only raises it anew. What, he asks, is meant by tensed verb forms such as 'was' and 'will be'? His answer may be given in the schema

S {was, is now, will be} P iff for some moment m, S *has* P at m & m
is {past, present, future}

where the italicized verbs are meant to be tenseless. He thus believes that tense can be reduced to A-characteristics and tenseless copulas. If this is right, then in saying that an event has been future and will be past, we are introducing a new A-series, this time of moments. And this brings back our contradiction, because every moment, like every event, is past, present, and future. If we try to get rid of the contradiction by saying of moments what we said earlier about events, our statement “means that the moment in question is future at a present moment, and will be present and past at different moments of future time. This, of course, is the same difficulty over again. And so on infinitely” (LePoidevin, p. 33).

Why is McTaggart so convinced that there is a contradiction in the A-series and a regress in any attempt to remove it? His thought on these matters can be made more understandable by presenting it with the help of a metaphor. He begins by supposing that the whole of history is laid out in a block comprising the B-series. He notes that in such a

series, there is no change and therefore no time, all events simply sitting there alongside one another on the B-axis. What can add time to such a universe? We must bring in the A-characteristics, letting the spotlight of presentness wash along the series in the direction from earlier to later. But wait! If the spotlight illuminates event *e* before it illuminates event *f*, then the events of *e's being present* and *f's being present* are both there on the B-axis, permanently related by the relation of earlier-than. Similarly, if the shadow of pastness falls on *e* before it falls on *f*, then *e's being past* and *f's being past* permanently stand in the B-relation of earlier-than and are thus always there on the B-axis. What we are saying implies that that *e* and *f* are both always past and always present—surely a contradiction, just as McTaggart alleges. If we seek to remove the contradiction by saying that the spotlight of the present falls on *e's being present* before it falls on *f's being present*, we are only embarking on a useless regress—again just as McTaggart alleges.

As noted above, few besides McTaggart have accepted his argument *in toto*, but many have accepted one half or the other. This gives rise to a great divide in the philosophy of time. One side accepts his first main premise while rejecting the second: the A-characteristics (or some surrogate for them) are indeed essential to time, but there is nothing wrong with that. The other side accepts his second main premise while rejecting the first: there is indeed a defect in the A-series, but a B-series by itself is all you need to have time. For obvious reasons, these two responses to McTaggart are often called “the A theory” and “the B theory,” though the names can be misleading.

There is an entire cluster of doctrines that tend to go together under the banner of the A theory and another opposing cluster under the banner of the B theory. (Other labels for

the two sides are the dynamic versus the static theory and the theory of passage or becoming versus the theory of the four-dimensional manifold.) The rival doctrines may be tabulated as follows:

The A Theory (Dynamic Time)	The B Theory (Static Time)
A1. Tense is an irreducible and indispensable feature of thought and language, reflecting a genuine feature of reality. Corollary: some propositions change in truth value with the passage of time.	B1. Tense is reducible or eliminable; reality is adequately describable without it. Corollary: every true proposition is timelessly true.
A2. The A-characteristics are successively possessed by all events, and they are not reducible to the B-relations.	B2. The A-characteristics are either delusive or reducible to the B-relations.
A3. The present is ontologically privileged: things present have a reality not belonging to things past or future.	B3. Past, present, and future are ontologically on a par: things past and future are no less real than things present.
A4. The future is open or indeterminate: some propositions about what is going to happen in the future are not yet either true or false.	B4. The future is as fixed as the past; every proposition must be true or false, and propositions have their truth values eternally (as noted in B1).
A5. Identity through time is <i>endurance</i> : numerically the same thing exists at many distinct times.	B5. Identity through time is <i>perdurantism</i> : a thing that lasts through time is a series of distinct temporal parts or stages, united by some relation other than identity.

In row 1, we have the debate between those who take tense as primitive and those who seek to reduce it to something else (as Smart once did when he suggested that ‘it will rain’ just means ‘rain occurs later than this utterance’.) In row 2, we have the debate between the A theory proper and the B theory proper, which is sometimes too quickly equated with the debate in row 1. (Arguably, tenses are not equivalents of the A-characteristics, but superior substitutes for them.) In row 3, we have the issue that divides *presentists* from *eternalists*—those like Augustine, who laments that his boyhood is no more, and those like the Tralfamadorians in Vonnegut’s *Slaughterhouse Five*, who do not cry at funerals because their departed loved ones exist and breathe at earlier

moments. In row 4, we have an issue that goes back to Aristotle's discussion in *De Interpretatione*: must the proposition *the captain will order a sea battle tomorrow* be true or false today, and if so, does that mean the future is in some way fixed or fated? Finally, in row 5 we have the issue (stated in David Lewis's terms) that divides those who believe in genuine continuants from those who accept an analysis of identity through time like that of D.C. Williams, who once observed that "each of us proceeds through time only as a fence proceeds across a farm"—that is, by having different parts at different moments or regions (Williams, 1951, p. 463).

As noted, a philosopher who holds a view in one of the columns will tend to hold the other views in that column as well. There is a certain amount of room for mixing and matching, however, and it should not be assumed automatically that the propositions in a given column must go together as a package deal.

Indeed, no one should hold *all* of the propositions in column A, for a little reflection shows that A2 is inconsistent with A3. If presentism is true, there are no things or events that are not present, and thus no items possessed of pastness and futurity. So if A3 is true, A2 is false.

The best combination among A1-A3 for a friend of dynamic time is arguably A1 and A3 without A2. Ironically, this would be an "A theory" without the A-characteristics, so the common name is not well chosen. McTaggart's combination was just the opposite, and this is arguably what led to the demise of time in his philosophy. His argument depends on reducing tense to the A-characteristics, and it also depends on making the eternalist assumption that the earlier and later portions of the B-series are equally real. A presentist could evade the argument by denying that an event is there before it becomes

present; rather, the event simply *becomes*—it comes into being and then as quickly passes out of being. Or better yet (since an ontology of things goes better with presentism than an ontology of events), a thing becomes F and then is no longer F.

The issue debated in rows 1 and 2 is sometimes put this way: does time *pass*, or is there simply a huge four-dimensional manifold with time as one of its dimensions? Some philosophers think the passage view may be refuted by asking a simple question: how *fast* does time pass? If the first second of the year 2050 is getting closer to us, there must be a rate at which it is doing this, yet any way of assigning the rate would be nonsensical or absurd. Are the seconds going by at the rate of one second per second? That is no rate at all. One second per hypersecond? That takes the first step in a preposterous series of time orders. So time does not pass.

When the argument is formulated that way, it presupposes a substantival theory of time—as though there were drops of time passing through an hourglass. Perhaps, then, the argument can be sidestepped by combining belief in dynamic time with a rejection of substantival time. Such is the combination espoused by Arthur Prior, the founder of tense logic. Prior represents tenses with operators, akin to modal operators: ‘Peter will sneeze’ becomes ‘It will be the case that Peter sneezes’, symbolizable as Fp , and ‘Peter sneezed’ becomes ‘It was the case that Peter sneezes’, symbolizable as Pp . The present tense is the default tense and needs no operator. With this apparatus, it is possible to articulate many propositions about the structure of time. For example, the density of time may be expressed as $(p)(Fp \rightarrow FFp)$. This formula would not be true if time were discrete, for if there were an immediately next moment and a proposition p true at it but not thereafter, Fp would be true and FFp false. Prior denies that time is a literal object, “a sort of snake

which either eats its tail or doesn't, either has ends or doesn't, either is made of separate segments or isn't;" rather, these issues can be formulated using propositional variables and tense operators in a way that makes no reference to time or its parts (Prior, 1968, p. 189).

Returning now to the question of time's passage, Prior suggests that the metaphor can be cashed out in tense logic as follows: there are true instances of the schema $Pp \ \& \ \sim p$ —it was the case that p , but is not now the case that p . When the matter is put that way, it is no longer obvious how awkward questions about the rate of time's passage are to be formulated.

PROBLEMS FOR PRESENTISM

Presentism is easily misunderstood. Presentists are not holocaust deniers; their insistence that nothing past exists is compatible with their affirming truths about what happened using tense operators. Nonetheless, presentism is not without its problems. Are there not past tense truths about individuals who no longer exist, for example, that Lincoln was wise and wore a beard? But how can there be such truths if Lincoln no longer exists to be a constituent of propositions about him? On this question, Prior bites the bullet and says there are no *singular* truths about objects that no longer exist, but only *general* truths—it was once the case that there was a man who was President during a civil war, etc., and who wore a beard. Other presentists find some presently existing entity for past-tense truths to be about—for example, the haecceity *being Lincoln*, a property that exists even if Lincoln does not, and which was formerly co-instantiated with the property of being wise.

What some regard as the fatal blow for presentism comes from the Special Theory of Relativity. The theory is often presented as resting on two postulates, the relativity of uniform motion and the constancy of the speed of light. Uniform motion is motion at a constant speed in a constant direction. The first postulate tells us that no experiment can determine that an object is in a state of absolute uniform motion, from which it is often concluded that it makes no sense to ascribe uniform motion. (If two objects are moving uniformly relative to each other, it is as correct to say that one is moving and the other at rest as vice versa.) The second postulate tells us that whether an observer is moving towards or away from a beam of light, the light's speed with respect to the observer will be the same. Einstein showed that when these two postulates are combined, many surprising consequences follow, including the relativity of simultaneity: two events that are simultaneous in one observer's frame of reference may be successive in another's frame, with no way of saying that either frame is uniquely correct.

Hilary Putnam has offered an argument against presentism based on Special Relativity and two other assumptions. One assumption (which Putnam calls the principle of "no privileged observers") is that what is real for you is real for me, assuming that you are real for me. This may be expressed equivalently as the assumption that the relation of being real-for is transitive:

1. If x is real for y & y is real for z , then x is real for z .

Putnam's other assumption is that in the context of Special Relativity, the presentist's core thesis that x is real iff x is present should be reformulated as ' x is real for y iff x is present for y ' and the latter in turn as ' x is simultaneous with y in the frame of y ':

2. Presentism implies: x is real for y iff x is simultaneous with y in the frame of y .

From 1 and 2, it follows that for presentists, the simultaneity relation we have just mentioned is transitive:

3. Presentism implies: if x is simultaneous with y in the frame of y & y is simultaneous with z in the frame of z , then x is simultaneous with z in the frame of z .

According to Special Relativity, however,

4. The relation in 3 (which Putnam calls ‘simultaneity in the observer’s frame’) is *not* transitive.

That is because if you pass right by me at a high relative speed, there will be events simultaneous with you in your frame that are not simultaneous with me in my frame, even though at the moment of passing, you are simultaneous with me in my frame.

Putnam concludes that presentism is false, and that I should acknowledge as real events belonging to your present even though they do not belong to mine.

If presentists do not wish to accept this conclusion, how should they respond to Putnam’s argument? There are three main options. One is to reject the transitivity of the real-for relation, as advocated by Sklar; in effect, this is to make reality itself as relative as simultaneity. A second is to reject Putnam’s construal of ‘ x is present for y ’ as ‘ x is simultaneous with y in the frame of y ’; alternative relativistic reconstructions of the present-for relation have been canvassed by Hinchliff and Sider. The third is to question Special Relativity, as has been done by Prior. This last response may strike some as an audacious denial of physics to make room for metaphysics, but it need not be that. It will probably not have escaped the reader’s notice that insofar as Special Relativity says *there is no such thing* as absolute uniform motion—not just that it is undetectable by any experiment—it ventures beyond physics into philosophy. One who questions the theory may be

questioning its verificationist auxiliary assumptions rather than anything that physics alone can teach us.

IS TIME TRAVEL POSSIBLE?

This question turns in part on the issues in rows 3, 4, and 5.

The physics of the last century is sometimes thought to imply an answer of *yes*, for two main reasons. First, the Special Theory of Relativity is sometimes thought to imply eternalism, as discussed above, and the eternalist view encourages us to take time travel seriously. If the assassination of JFK is there, several decades prior to us on the time line, why couldn't we go there and witness it? (Conversely, presentism is sometimes thought to rule out time travel, on the ground that if the past and the future are not there, there is literally nowhere to go.) Second, the General Theory of Relativity is now believed to imply the possibility of closed timelike curves, which might be exploited by time travelers. Einstein's field equations enable one to calculate the spacetime structures induced by various configurations of matter, and in 1949, Kurt Gödel showed that there are possible configurations of matter that would generate closed timelike curves—temporal paths along which an event can precede other events which precede itself. An object part of whose lifeline lay along such a curve could (in a sense) visit its own past. Interestingly, Gödel's own conclusion from his discovery was quite different: he thought *real* time could not violate the irreflexivity of precedence, so he took the possibility of loops in time to show that time is ideal in something like Kant's sense.

Even if permitted by physics, travel to the past may nonetheless be forbidden by logic or metaphysics. An entrenched axiom is that no one can change the past. If we could

travel to the past, why could we not change it, even in paradoxical ways such as by killing one's grandfather or infant self? Science fiction writers sometimes take pains to have their characters leave the past undisturbed; for example, they view dinosaurs from magically suspended walkways so as to leave no footprints. But of course the mere presence of the time traveler as an observer would constitute a change in the past if he had not been there the "first" (and only) time around. Therefore, in consistent time travel tales, the traveler "always" made his visit—the visit does not change the past, but was always part of it. (As David Lewis has it, a temporal stage of the traveler was permanently present at the scene. Lewis's stage view explains how it is possible for the traveler to interact with his infant self: such interaction occurs between stages of the same person that are contemporaneous in "external" time but one later than the other in "personal" time.) Because his actions are already woven into the past, a time traveler cannot kill his grandfather or his infant self; in history as it was, grandfather lived and the traveler failed to kill him, if he tried.

This way of preserving the past from change may arouse fears of fatalism. If in fact grandfather lived to sire my father, am I not fated to fail in my attempts to kill him? And if in history as it happened, I emerged from a time machine in 1920 that I enter (entered? will enter?) in 2020, am I not fated to enter the time machine in 2020, or at least at some time? To do otherwise would be to do something at variance with past truth. In reply, some argue that time-travel arguments for fatalism add nothing to more general arguments for fatalism based on applying the law of bivalence to the future, such as the following:

1. It was either true yesterday that I would push the nuclear button tomorrow or true yesterday that I would not.

2. In the former case, I *must* push the button tomorrow
3. In the latter case, I must *not* push it.
4. Either way, only one course is open to me.

A common reply to such Aristotelian worries is that all that follows from the supposition that it was true yesterday that I would push the button tomorrow is that I *will* push it, not that I *must*. It could be maintained similarly that although in 2020 I certainly *will* enter the time machine from which I emerged in 1920, it is not true that I *must*. So a good case can be made that time travel imposes fatalistic constraints on time travelers only if Aristotelian arguments from bivalence impose fatalistic constraints on us all. So which is it, freedom for time travelers or fate for us all? Space and time do not permit an answer to this question here.

See also ANTINOMIES; ARISTOTLE; CHANGE; CONTINUANT; FATALISM; GÖDEL; HAECCEITY; IDENTITY OF INDISCERNIBLES; KANT; LEIBNIZ; LEWIS; McTAGGART; NEWTON; PRINCIPLE OF VERIFIABILITY; SMART, J.C.C; TEMPORAL PARTS; D.C. WILLIAMS; ZENO OF ELEA.

