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SPACE, TIME AND THE LIMITS OF HUMAN UNDERSTANDING

Foreword by John Stachel and
Afterword by Noam Chomsky

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Chapter 5
From Time to Time

Nathan Salmon

5.1 I

The apparent verdict of current theoretical physics is that the prospect of time travel does not violate general relativity. The philosopher interprets this as a judgment that time travel is, at a minimum, logically consistent with general relativity. It directly follows from this judgment that general relativity and time travel are each themselves consistent, hence that time travel is logically possible. On the other side of the coin, philosophers have argued that time travel of the sort depicted in the classic H.G. Wells' novella, *The Time Machine*, is inconsistent with common sense—for example the notion that one who travels to a past time when his paternal grandfather is alive but has not yet sired his father, could murder his own grandfather at that earlier time. This is the famous *grandfather paradox*. If the reasoning is sound, then Wellsian time travel—as depicted in *The Time Machine*, in numerous other science-fiction stories, in thought experiments, and the like—is metaphysically impossible and perhaps conceptually incoherent.

Time travel essentially involves someone or something changing its temporal location from one time to another in a manner analogous to motion in space, i.e., change in spatial location over time. The first of these temporal locations is the *time of origin*, t_o, the second is the *time of destination*, t_d. Time travel essentially

The thoughts expressed here are a result of ruminations on the first (and much better) film adaption of H. G. Wells' novella The Time Machine and on trenchant observations made by Hilary Putnam in his paper "It Ain't Necessarily So". The essay benefitted from discussions with C. Anthony Anderson, Mark Fiocco, Stephen Humphrey, Teresa Robertson. Heather Salazar, and the late Anthony Brueckner.

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involves something embarking on a purely temporal voyage, "moving" through time in a manner analogous to spatial motion. In one sense, mere temporal persistence is a kind of time travel; it is motion from present to immediate future at a rate of one (second per second), the constant rate of the passage of time. Insofar as ordinary persistence is a kind of temporal motion, it is arguably impossible *not* to travel in time. For what would it be to remain stationary in time?

Wellsian time travel is continuous temporal motion through time that deviates from standard temporal motion. It is traversing a span of time during some *other* interval of time. It essentially involves changing temporal location other than at the rate by which time passes from t_o to t_d—deviating from the timeline segment that begins with t_o (without also remaining in that timeline), traveling temporally other than forward and at the same rate as the passage of time, and finally "arriving" at the timeline segment that begins with t_d. Henceforth I shall normally use the phrase 'time travel' and its cognates to mean Wellsian time travel.

I here undertake a philosophical investigation into the concept of Wellsian time travel. I shall also consider the prospect of backward (or retro-) causation as a genuine possibility, in the weak sense of mere logical consistency. That is, I shall assume that there is no formal contradiction in the very idea of A causing B though B precedes A. Backward time travel, at least taken in conjunction with common sense, immediately entails backward causation. (The grandfather's future progeny causes his own death.) The champion of Wellsian time travel is committed to this assumption. Gainsayers may object, but they would be mistaken. Experience with the law demonstrates that the assumption is correct.[1]

Objections to Wellsian time travel along the lines of the grandfather paradox and similar bilking arguments typically should be regarded as modal arguments to the effect that backward time travel has the consequence that someone can do or be something that it is impossible to do or be (e.g., be sired by a father who never exists). When the argument's structure is laid bare, a significant weakness is immediately exposed. The premises do not support the conclusion that Wellsian time travel is impossible. At most they yield only that backward time travel is impossible.[2] The prospect of forward time travel is left unscathed.

[1]Backward causation by judicial decree is causation between institutional "events", not between brute facts, but backward causation it is. It is not analytic that if A causes B, then B does not precede A.

[2]The argument is valid only in modal logics stronger than $\boldsymbol{T}$. I believe $\boldsymbol{T}$ is the correct logic of metaphysical modality, so that the argument is fallacious. The argument can be alternatively formulated so that it is valid even in $\boldsymbol{T}$.

5.2 II

As David Lewis noted, the concept of time travel presupposes a distinction between two kinds of time.[3] The time traveler is a two-timer (in at least one sense). First, there is *real time*, t_r, through which the time traveler travels. This is also called ‘common time’, ‘objective’, ‘external’, ‘coordinate’, ‘global’, ‘local’ (yes, both!), and more. It is also called simply ‘time’. Real time is to time travel as physical space is to spatial motion: It is the “space” through which the time traveler travels. In addition there is the time traveler’s *proper time* (‘rest’, ‘home’, ‘clock’, ‘process’, ‘personal’, ‘time-traveler’, ‘intrinsic’, ‘subjective’), t_p. A time traveler’s proper time is what the traveler’s wristwatch tracks—as with the inattentive globe trotter who does not diligently readjust a personal timepiece when travelling across time zones. Proper time is to time travel as real time is to spatial motion. It is the dimension over or during which the change in location occurs. The real time of origin t_o coincides with the proper time of “departure”, immediately after which proper time begins deviating from real time. The proper time at the real destination time t_d is the time traveler’s time of arrival.

Trivially, real time and proper time each flows from past to future at a fixed rate relative to itself of one (second per second), irrespective of the time traveler’s circumstances. To that extent, both kinds of time are objective. There is the mundane circumstance of trivial temporal motion if, and only if, the would-be time traveler moves forward through real time at the same rate as the passage of real time, and thus neither gains nor loses any real time over proper time. In it the two kinds of time coincide exactly; where there is only trivial temporal motion, $t_p = t_r$. There is Wellsian time travel if and only if the intrinsic arrival time is not the real destination time. The proper time of the Wellsian time traveler gains on real time, lags behind real time, reverses with respect to real time—or maybe freezes with respect to real time.

Imagine an amusement-park conveyance ride called *Travels through Time*. The rider is seated on a bicycle labeled ‘TIME MACHINE’. The bicycle sits upon the conveyer belt at an illuminated position labeled ‘HOME TIME’. The conveyance and illumination each move forward, carrying the rider and bicycle along with them, at a constant rate of one inch per second. Second by second, inch by inch, the rider and bicycle move their way through the long, darkened corridor labeled ‘HALL OF TIME’, their changing position constantly illuminated. Through the mist, to the right and left of the conveyer belt are signs pointing the way ahead and marked ‘FUTURE’ and other signs pointing backward and marked ‘PAST’, amidst scenes and photographs from history, all arranged in chronological sequence. The rider is free simply to maintain HOME TIME position on the conveyer belt, sit back, allow the conveyance to do all the transporting labor, and enjoy the show. Conveyer and rider then move forward through the HALL OF TIME in unison. But

[3]“The Paradoxes of Time Travel”, *American Philosophical Quarterly*, 13 (April 1976), pp. 145–152, at p. 145.

the rider is encouraged to change position on the conveyer belt by cycling either forward or backward atop the moving belt. In so doing, the rider moves not merely relative to the HALL, but also relative to the HOME TIME conveyer position, which is itself in motion relative to the HALL.

It may be taken as a definition of 'time travel' that there is a process (the *temporal voyage*) that something x (the *time traveler*) undergoes immediately following upon a particular real time t_o (the *time of origin*), that has a duration d_p (a positive quantity) in x's proper time, and as a result of which when x's proper time is $t_o + d_p$ (the arrival time), x is at a real t_d other than $t_o + d_p$. A *time machine* is any device that produces Wellsian time travel. In Wellsian time travel there are no restrictions concerning the origin time, the proper-time duration, or the real destination time. These definitions are satisfactory only to the extent that the presupposed notion of proper time is independently and antecedently understood. In particular, the notion thus defined cannot be invoked to define proper time. The latter might be independently understood operationally, in terms of the time traveler's "clocks," the temporal order of the time traveler's intrinsic periodic processes —circadian rhythm, digestion, growth, sleep, reasoning, learning, other mental processing, etc., and especially entropy (aging, deterioration, degradation, or decay).[4]

Some facts of time travel follow immediately from the concept. Among these truisms are the following facts about any temporal voyage:

TT1 The time traveler exists at the real time of origin, t_o.
TT2 The time traveler exists at the real time of destination, t_d.

Both *TT1* and *TT2* follow immediately from the fact that the statement 'At time t, x is located at ℓ' analytically entails 'x exists at t'.[5]

Assume that the temporal voyage proper-time duration d_p is not zero. During the temporal voyage the rate of the passage of proper time deviates from that of real time. A single unit of proper time (e.g., 1 min) is of different duration from the same unit of real time. Without this deviation between intrinsic and real time there is only trivial temporal motion. There is a temporal exchange rate, which may vary during the temporal voyage. If 1 min of proper time uniformly buys the time traveler 1 h of real time, then, assuming there is conservation of time variance,

4The proposed definition is essentially Lewis's characterization of time travel (*op. cit.*, p. 145), which is often taken as a definition. Since the temporal voyage duration d is a measure of intrinsic ("personal") time, not of real time, Lewis's characterization also presupposes the notion of proper time, and therefore cannot be used to define the latter. Lewis proposes that proper time be defined functionally rather than operationally. (He does not provide an actual definition.).

5If it is assumed that 'x moves from ℓ_1 at t_1 to ℓ_2 at t_2' analytically entails 'Between t_1 and t_2, x traverses a path from ℓ_1 to ℓ_2', then we might have the further result that the time traveler exists also during its temporal voyage, if the temporal-voyage duration $d > 0$. If it is assumed furthermore that motion requires traversing a continuous path, then we might have the further result that the time traveler exists continuously during its temporal voyage, if the temporal-voyage duration $d > 0$.

1 min of real time lasts only one second of proper time. Proper time is therewith contracted relative to real time. In science-fiction stories, proper time is typically contracted during a temporal voyage rather than dilated, but the reverse is conceptually possible. (Arguably it is even actual.)

TT3 Barring multiple temporal voyages, the time traveler's proper time, t_p, coincides with real time, t_r, at the time of origin, t_o, and deviates from real time beginning immediately thereafter.

An object's *(average) rate of time travel* over a proper-time interval *i* is the ratio of real time spanned during *i* (a positive or negative quantity) to elapsed proper time (the positive quantity of time in *i*), $\Delta t_r/\Delta t_p$. In Wellsian time travel, the time-travel rate may be any positive or negative ratio without restriction. Rather than express $\Delta t_r/\Delta t_p$ as a ratio between interval lengths, I shall convert it to a scalar, e.g., for the particular time-travel rate *spanning backward 4 s of real time for every 3 s of elapsed proper time* I write '$ttr = -1.33$'. If the time traveler is transported to another time instantaneously, then the ratio of spanned real time to elapsed proper time is division by zero, hence *ttr* is undefined. The greater its range of time-travel rates, the more powerful the time machine.

The average time-travel rate over an entire temporal-voyage *v* is $(t_d - t_o)/d_p$. A simple relationship thus obtains among the origin time (t_o), the real destination time (t_d), the temporal-voyage proper-time duration (d_p), and the temporal-voyage time-travel rate (ttr_v):

$$t_d = t_o + ttr_v\left(d_p\right).$$

In the special case where $ttr_v = 1$, $t_d = t_o + d_p$, i.e., the intrinsic arrival time is the real destination time. There is Wellsian time travel over the course of the temporal voyage *v* if and only if $ttr_v \neq 1$. This is the case if and only if there is non-zero acceleration or deceleration both immediately after the temporal-voyage origin time t_o (immediately after which proper time begins to deviate from real time) and at the proper time of arrival $t_o + d_p$ (when proper time resumes flowing at the constant real-time rate). A time traveler may also accelerate or decelerate during a single temporal voyage. An object's *instantaneous time-travel rate* during a sub-voyage is the limit of the average time-travel rate $\Delta t_r/\Delta t_p$ as Δt_p approaches 0. The real time reached during a temporal voyage *v* is a function of proper time, $t_r = \boldsymbol{\rho}_v(t_p)$. The instantaneous time-travel rate is the first time derivative, dt_r/dt_p. To simplify discussion we shall assume that the time traveler travels at a uniform time-travel rate throughout the temporal voyage—no acceleration or deceleration between the origin and arrival times—so that dt_r/dt_p remains constant throughout the temporal voyage (e.g., 60 = 1 h of real time to 1 min of proper time).

The *gain* of real time over proper time during a proper-time interval *i* is the total quantity of excess real time purchased during *i*, $\Delta t_r - \Delta t_p$. An object's *(average) rate of gain*, *gr*, of real time over proper time during a proper-time interval *i* is the ratio of gained real time to elapsed proper time, $(\Delta t_r - \Delta t_p)/\Delta t_p$. This figure is the difference between the time-travel rate and the constant no-time-travel rate of one unit of real time per unit of proper time, i.e., $gr = \Delta t_r/\Delta t_p - 1$. The gain over the entire temporal voyage is the difference between the quantity of spanned real time and the proper-time duration, $t_d - t_o - d_p$. This is also the difference between the real destination time and the intrinsic arrival time, $t_d - (t_o + d_p)$. If the proper-time duration is 5 min and the average time-travel rate is 12, so that the time traveler buys one real hour in just 5 intrinsic minutes (arriving 1 h into the future of the origin time), then there is a gain of 55 min of real time over proper time. By contrast, if the duration is 5 min and the average time-travel rate is −12, so that the time traveler arrives one hour into the past after only 5 min, then there is a loss of 65 min (a gain of −65 min) of real time over proper time. Gain rates reflect the asymmetry of time.

The analog of time-travel rate in the amusement-park ride is the rider's linear velocity relative to the real HALL OF TIME—the speed at which the rider moves through the HALL, forward (positive) or backward (negative). The analog of the gain rate is the rider's linear velocity relative to the HOME TIME position on the conveyance—the speed at which the rider moves ahead (positive) or behind (negative) the HOME TIME position, which is itself in motion relative to the HALL. If the rider simply maintains position on the conveyance, the former velocity is a ratio of 1 (inches:seconds), i.e., one inch (representing one second) of progress through the corridor for every second of rider time, while the latter velocity is 0. If the rider cycles backward atop the conveyance at two inches per second, the rider therewith travels relative to the HOME TIME position at a rate of −2. However, since the HOME TIME position is forging ahead relative to the HALL at 1, the rider therewith travels relative to the HALL at a ratio of only −1. Backward time travel is harder work than forward, because of relentless time pressure.

Time-travel rates fall into several categories, each category corresponding to a unique time-travel orientation. The most distinctive categories are: time-travel rates greater than 1; 1 itself; negative time-travel rates; those between 0 and 1; and 0 itself. These are collectively exhaustive of all time-travel rates. Among negative time-travel rates are three distinctive sub-categories: −1; those less than −1; and those between −1 and 0. Interest is typically focused on time-travel rates that are either greater than 1 or less than 0. There is *forward time travel*, whereby the time traveler gains on real time, if and only if the time-travel rate is greater than 1. If the time-travel rate is uniformly 1.33, then the time traveler travels forward 1.33 s through real time for every second of proper time. There is *backward time travel*, whereby the time traveler travels in reverse through real time, if and only if the time-travel rate is negative.

There are three *limit rates*, at which the orientation of time-travel takes on a very distinctive character: 1, 0, and −1. As we have seen, the time-travel rate is exactly 1 if and only if there is only trivial time travel. The time-travel rate is exactly 0 if and only if there is *freeze-frame time travel*, in which the time traveler remains stationary with respect to real time. This is the bleak and lonely circumstance in which time literally *stands still* for the time traveler, who is stalled at some real time. (Notice, however, that there is no real-time interval during which the time traveler is

Table 5.1 For most readers, your current time-travel rate = 1

Time-travel rate (*ttr*)	$ttr < -1$	-1	$-1 < ttr < 0$	0	$0 < ttr < 1$	1	$ttr > 1$
Time-travel orientation	Fast backward	Reverse real time	Slow backward	Freeze frame	Lag-behind	No time travel	Forward
Gain rate (*gr*)	$gr < -2$	-2	$-2 < gr < -1$	-1	$-1 < gr < 0$	0	$gr > 0$

in this peculiar circumstance.) Backward time travel in *reverse real time* is traveling to the past at a rate of -1. At this time-travel rate, ten minutes into the temporal voyage the time traveler travels exactly ten minutes into the past.

The time-travel rate is a positive fraction, more than 0 but less than 1, if and only if there is *lag-behind time travel*, in which time traveler moves forward in time but at a slower rate than the passage of real time. This is a circumstance in which the real world appears to the time traveler to be moving in slow motion, because a single second of proper time is of shorter duration that one second of real time.[6] Table 5.1 provides various time-travel orientations and their corresponding rates.

At the end of the temporal voyage, the proper and real times are distinct but the flow of the former re-synchronizes with the latter. Proper time returns to moving forward at a rate of exactly one real second per time-traveler second. The time-travel rate returns to exactly 1, the gain-rate to 0.

5.3 III

What real time is it *during* the temporal voyage? The narrative of a time-travel story typically follows proper time. In telling a time-travel story in time-traveler chronological sequential order, the storyteller implicitly relies on an important fact: There is a function, $t_r = \boldsymbol{\rho}(t_p)$, that specifies what real time it is at any particular proper time. If there is only one temporal voyage v, and the real time reached during v is given as a function of proper time, $t_r = \boldsymbol{\rho}_v(t_p)$, then $\boldsymbol{\rho}$ may be given as follows:

If t_p is earlier than the time of origin ($t_p \leq t_o$), then $\boldsymbol{\rho}(t_p) = t_p$;
if t_p is within the temporal voyage ($t_o < t_p < t_o + d_p$), then $\boldsymbol{\rho}(t_p) = t_o + \boldsymbol{\rho}_v(t_p - t_o) = t_o + ttr_v(t_p - t_o)$; and

[6]Special relativity has the confirmed consequence that a dilation of time relative to a frame of reference is achieved simply by moving about relative to that reference frame. Arguably, anything that is in motion relative to a reference-frame *ipso facto* has a time-travel rate less than 1 with respect to that reference-frame. It is highly relevant, however, that this phenomenon is not typically thought of or described as a form of time travel. Instead it is thought of and described as a "slowing" of the traveler's time relative to a perspective regarded as stationary. The present discussion envisions that a single frame of reference is held fixed throughout.

if t_p is the same as or later than the proper time of arrival ($t_p \geq t_o + d_p$), then $\boldsymbol{\rho}(t_p) = t_p + t_d - (t_o + d_p)$.

Upon arrival and afterward, the real time is the sum of the proper time and the gained real time. In particular, $\boldsymbol{\rho}(t_o + d_p) = t_d$, i.e., when proper time is the time of arrival, real time is the destination time.

In forward time travel ($ttr > 0$) there is a 1–1 function, $t_p = \boldsymbol{\tau}(t_r)$, that specifies what proper time it is at any particular real time. This function is simply the converse of $\boldsymbol{\rho}$. It may be given as follows:

If $t_r \leq t_o$, then $\boldsymbol{\tau}(t_r) = t_r$;
if $t_o < t_r < t_d$, then $\boldsymbol{\tau}(t_r) = t_o + (t_r - t_o)/ttr_v$;
and if $t_r \geq t_d$, then $\boldsymbol{\tau}(t_r) = (t_o + d_p) + t_r - t_d$.

When real time t_r is later than or the same as the destination time t_d, proper time t_p is later than the arrival time $t_o + d_p$ by exactly the same interval that t_r is later than the destination time t_d.

If the temporal voyage is backward, the correspondence of proper time to real time is one-many, hence not a function. This points to a significant asymmetry between forward time travel and backward. The converse of the one-many correlation is $\boldsymbol{\rho}$. For times within the negatively spanned real time, there are at least two different proper times: one before the temporal voyage and one during as seen from the inside. If the spanned real time is short enough, corresponding to a single real time t_r earlier than t_o, there can be three different proper times: one before, one during, and one after the temporal voyage. This correlation between real times and proper times is also highly systematic.

5.4 IV

The concept of proper time is integral to the concept of time travel. If the primary philosophical question concerning time travel is whether it is a metaphysical possibility, then a secondary but important philosophical question concerning time travel is: W*hat exactly is proper time?* What also is the nature of the correspondence between proper and real time? Lewis writes, "I [distinguish] time itself … from the *personal time* of a particular time traveler … the time-traveler's personal time … isn't really time, but it plays the role in his life that time plays in the life of a common person" (*op. cit.*, p. 146). Lewis's concession that proper time is not genuinely time is more serious than he recognizes. It would, if correct, exclude the very possibility of Wellsian time travel. Proper time plays the functional role of time in the analogy with spatial motion. The time traveler moves from one real time to another during an interval spanning from one proper time to a later one. Time-travel rate is defined in terms of elapsed proper time, not elapsed real time; the instantaneous time-travel rate is the time derivative of $\boldsymbol{\rho}_v$ with respect to proper time, not with respect to real time. If time travel, defined as the temporal analog of spatial motion, is genuine—if continuous nonstandard re-location in real time over proper time is a possible phenomenon—then proper time must be genuine time of some kind, and yet not real time. Since real time is just time (*simpliciter*), the very notion of time travel requires that proper time be a sub-phenomenon of real time.

Real time is made up of real times, the values of 't_r'. Proper time is made up of proper times, the values of 't_p'. If proper time is time of a certain kind—as it must be for time travel to be the temporal analog of spatial motion—then proper times are times of a certain kind. Are the values of 't_p' of a different character from those of 't_r'? For example, is the intrinsic arrival time, $t_o + d_p$, metaphysically different in nature from the real destination time, t_d? Is proper time a subjective phenomenon of some sort, a shadow of real time? Is the intrinsic arrival time, or is proper time while *en route*, perhaps an alien time, outside and orthogonal to the real timeline?

Proper time is none of these things. It is not subjective in any significant sense. Nor is it an alien time, nor metaphysically peculiar in any way.[7] If a time traveler from t_o were to arrive at t_d at an alien time, it would make no sense to attempt to place the intrinsic arrival time as earlier than, later than, or identical with, any particular real time. Proper times are times like any other. For each proper time t_p, there is a particular real time t_r such that t_p just *is* t_r. In particular, the proper time of arrival is identical with a particular real time, one that is not the real destination time. It is just the particular real time $t_o + d_p$ that is later than (subsequent to, downstream on the real timeline from) t_o by exactly the duration d_p of the temporal voyage. Contrary to Lewis, *the proper-time dimension is simply ordinary time*.

Even the proper times that elapse during the temporal voyage itself are identical with particular real times. In fact, despite *TT3*, the duration of an *en route* proper time is exactly the same as that of the real time with which it is identical. They are the very same thing. Proper times are just the real times from the departed time-frame—each one shining temporarily in sequence, then replaced, one following upon another, with real presentness flowing forward in step as if nothing remarkable has just taken place. Indeed, nothing remarkable happens intrinsically to the times themselves; it is the time traveler that undergoes a remarkable process. The time traveler's proper timeframe deviates from the timeframe of origin. Despite the time traveler's deviation from the original timeframe, that timeframe itself is unscathed; time continues to flow even if un-graced by the time traveler's presence. Both during and after the temporal voyage, the departed timeframe is identical with the traveler's proper time.

Proper times are also real times. Whether a time is designated 'real' or alternatively as 'proper' depends on whether it is treated as the value or the argument of

[7]Lewis, *op. cit*., argues that intrinsic ("personal") time is not a temporal dimension orthogonal to real ("external") time (p. 145). His instinct is correct but his argument is fallacious. Contrary to his major premise, one who travels backward in time to visit with childhood friends is at the same real time as his/her friends but his/her proper time is then indeed different from theirs. Lewis's claim that proper time "isn't really time" is also importantly incorrect. What are different are the time traveler's relations to time.

$\boldsymbol{\rho}$. Although every proper time is a real time, if Wellsian time travel is genuine, then the correspondence $\boldsymbol{\rho}$ between a proper time and a real time is not strict identity.

If proper times are just real times, and yet *TT3* is a fundamental truism about time travel, is time travel then metaphysically impossible? On the other side of the coin, if time travel is possible and governed by *TT3*, how can proper times be real times?

As a prelude to answering these questions, we must first engage in a different line of inquiry. What timeline segment does the time traveler persist in immediately following the temporal voyage? Is it a proper timeline, to be treated as an argument to $\boldsymbol{\rho}$? Is it a real timeline, to be treated as a value of $\boldsymbol{\rho}$? Or is the time traveler at two different timelines, both proper and real time simultaneously, i.e., both at a single real time?

In absolute time—alternatively, within a single frame of reference—the answer must be that the post-voyage backward time traveler persists in real time and not in proper time. Otherwise the time traveler would remain in the original timeframe; there would be no genuine time-travel *departure*, as such. Proper time is a logical construct generated by the temporal order and rhythm of the time traveler's "clocks" (periodic processes of deterioration and the like)—a genuine timeframe, to be sure, but one through which the backward time traveler does not persist at all (unless the time traveler does so independently of the temporal voyage, e.g., by engaging in a separate temporal voyage). The time showing on the time traveler's personal timepiece upon arrival is a reading of his/her proper time.

What timeline segment does the backward time traveler persist in *during* the temporal voyage? Here again, the answer has to be that the backward time traveler is at real time, even if proper time is dilated or contracted relative to real time. Indeed, each time during the voyage may be seen as a layover arrival/destination time. The layover is of the best kind: very short but not too short. (It is in fact instantaneous, but that is long enough.) If the time traveler passes through the Roaring 20's on the way to 1,000,000 B.C., then the traveler existed during the Roaring 20's, even though (as the traveler might say) "it went by very fast … and backward".

This is more or less how time travel is depicted in *The Time Machine*. The Time Traveler witnesses the world change (or return to its pre-change state) before his very eyes. But there is a flaw in Wells' reasoning about Wellsian time travel. The Time Traveler is there—or rather, he is *then*—at each real time through which he passes. If he is indeed "then", why is it that the people around him at that very time do not see him there? He sees them; they should see him as well. Unless something very strange is occurring, they would indeed see him—and he would appear to be behaving peculiarly, moving and talking very slowly … and backward.

From t_o forward, proper time is just the real time of the time-traveler's original timeframe. Proper time corresponds to the position marked 'HOME TIME' on the amusement-park ride. Proper time *is* home time, the very timeframe that the time traveler left behind. It is analogous to the international traveler who upon arriving at LAX says "I'm on Asian time". Proper time is the temporal analog of jetlag. It is *time-machine lag*. Proper time is evidently a construct of a certain kind, based entirely on the progressively changing states of the time traveler's intrinsic temporal processes.

In labeling a time 'proper' rather than 'real', we are not distinguishing it in its nature from time as we know it. In particular, we are not positing a subjective, shadowy, parallel temporal dimension orthogonal to real time. Rather, we are marking time off in terms of the time traveler's relations to it. The rationale for calling a time 'proper' rather than 'real' concerns the relation that the time traveler bears toward it. The (nontrivial) time traveler is at a particular time, and therewith bears a different relation to a different time, the latter time being labeled the time traveler's 'proper time'. Let us say that the time traveler is *at* real time and *on* proper time. The time traveler is *on* one time when *at* a different time; the time the traveler is at is called 'real time'; the time the traveler is on is called 'proper time'. Everything is on its proper time. Most of us are also on real time. The backward time traveler is not at proper time when on it. Asian time is a real time, but the jetlagged traveler is not at it. Analogously, *proper time is time, but the post-voyage backward time traveler is not at it.*

If something is travelling through time at a rate of 60, then one second of proper time buys 1 min of real time. A second of time lasts exactly 1 s, a minute exactly 1 min, an hour exactly 1 h. One must resist the temptation to think that the time traveler is at an hour for only a minute. Rather, the time traveler remains *on* a single minute while *at* an entire hour. The time traveler is at a time even if the intrinsic clocks are on a different timeframe.

5.5 V

Someone who is about to travel back to 1,000,000 B.C. *was there already*—or rather, the time traveler was *then* already. The soon-to-be time traveler already existed in prehistoric times. The pre-voyage time traveler visited the prehistoric world in pre-history, when it was present (in the non-indexical sense). The time traveler is about to cease to be. In general, if a soon-to-be time traveler is "about," in proper time, to travel to a past time t_d, then the traveler was *already* at t_d before the temporal voyage. Moreover, since the soon-to-be backward time traveler is really about to *depart* from the current real timeframe, the time traveler is not about to arrive at t_d; the traveler is about to cease to exist. Rejecting either of these truisms leads to a serious misunderstanding of what time travel is supposed to be. More generally, we have the following additional fact about any backward temporal voyage:

TT4 The backward time traveler does not exist at the particular time $t_o + d_p$—unless the traveler either exists at an earlier time and simply persists to $t_o + d_p$, or embarks on a separate temporal voyage and travels to $t_o + d_p$ (or both).

We do not make the claim about forward time travel analogous to *TT4*. Real-time $t_o + d_p$ is the time that the time traveler is on upon arrival at t_d. Where $ttr > 1$ and $d_p > 0$, $t_o + d_p < t_d$ and therefore,

$$\boldsymbol{\tau}\left(t_o + d_p\right) = t_o + d_p/ttr < t_o + d_p.$$

That is, in forward time travel, if the intrinsic duration d_p is non-zero, then $t_o + d_p$ precedes the destination time t_d, and therefore the proper time corresponding to real-time $t_o + d_p$ precedes $t_o + d_p$ itself. The proper time corresponding to $t_o + d_p$ is still within the temporal voyage.

TT5 The forward time traveler whose time-travel rate is greater than 1 is *en route* to the destination time t_d at the particular time $t_o + d_p$.

This is in keeping with *TT3*. The contrast between *TT4* and *TT5* points to another asymmetry between forward time travel and backward.

Putting *TT2* together with *TT4* and *TT5*, we obtain a puzzling result: At the proper arrival time $t_o + d_p$, the fast-forward time traveler is not yet at the real destination time t_d; worse yet, the backward time traveler does not even *exist* at $t_o + d_p$ (except in special circumstances and for independent reasons). Either way, *the time traveler makes it to the real destination time, but does not arrive there at the proper arrival time*. How is this possible?

The seemingly bizarre fact is made possible by the distinction between being at a time and being on it. When the time traveler is on t, the traveler is at $\boldsymbol{\rho}(t)$. Whether the traveler is at a time that the traveler is on is another matter. The time traveler is on the proper arrival time at the real destination time, but is not then at the proper arrival time. At the proper arrival time the time traveler is not on it. The backward time traveler is not at the proper arrival time at all (again, except in special circumstances).

The phenomenon generally referred to as 'time travel' is so-called only insofar as it is viewed from the perspective of the agent undergoing the process. From this perspective proper time is time *simpliciter*. But from the perspective of real time—the default perspective—it emerges that the phenomenon in question is not objectively temporal re-location. It is only temporal re-location when seen from the inside. As seen from the objective observor's contrasting vantage point, the object undergoing the process is undergoing a change, but not a change of temporal location (other than ordinary persistence). Rather, *the change is a de-synchronization of the object's intrinsic temporal processes with the passage of real time*. Viewed from the perspective of spectator, the object's intrinsic "clocks" (aging, deterioration, etc.) are running slow, or fast, or backward, or jumping instantaneously. Importantly, it is a phenomenon intrinsic to the object undergoing the process. What looks from the inside like temporal re-location is, as seen by the spectator, a diachronic recalibration of the object's temporal processes.

An object's *(average) rate of passage of proper time* over a real-time interval i is the ratio of proper time spanned during i (a positive or negative quantity) to elapsed

Table 5.2 For most readers, your current proper-time passage rate = 1

Proper-time passage rate (ptr)	$ptr < -1$	-1	$-1 < ptr < 0$	0	$0 < ptr < 1$	1	$ptr > 1$
Proper-time orientation	Fast backward	Benjamin button	Slow backward	Suspended	Slow	Perfect time	Fast
"Time-travel" orientation	Slow backward	Reverse real time	fast backward	Instantaneous	Forward	No time travel	Lag-behind

real time (the positive quantity of time in *i*), $\Delta t_p/\Delta t_r$. Likewise, an object's *instantaneous rate of passage of proper time* is the limit of $\Delta t_p/\Delta t_r$ as Δt_r approaches 0. The proper-time passage rate is thus the reciprocal of the (so-called) time-travel rate, the instantaneous proper-time passage rate the reciprocal of the instantaneous time-travel rate. An object is on real time if, and only if, its proper-time passage rate is 1. The spectator's perspective yields an inversion of the time-traveler's perspective. Table 5.2 provides various proper-time orientations with respect to real time, their corresponding passage rates, and corresponding "time-travel" orientations.

From the passive spectator's perspective, and from the perspective of the non-participant, so-called time travel is ordinary persistence, or discontinuous persistence, coupled with very peculiar phenomena—walking, talking, processing, aging, and deteriorating too slowly, or too quickly, or too abruptly, or too backward. In particular, from the spectator's vantage point the phenomenon of so-called backward time travel is persistence together with both a reversal of the subject's intrinsic processes and a philosophical profanity: backward causation. A backward time traveller's presence in 1912 was caused by events that would transpire years later, well after their effect. The causation is forward in proper time but backward in real time.

On this re-conceptualization of time travel, the notion of *freeze-frame time travel* corresponds to an instantaneous jump in proper time. The corresponding proper-time passage rate is division by zero, hence undefined. For the freeze-frame time traveler it is *as if* time were passing, yet this does not occur during any interval of real time. In effect, while *en route* to t_d the freeze-frame time traveler is ejected from the flow of time into a temporal limbo.

One possible phenomenon often referred to as 'time travel' is perfectly coherent, including backward time travel. There is no logical inconsistency in the idea of an individual's intrinsic temporal processes running backward. However, so-called backward time travel, construed as taking place over real time, involves an individual popping into existence *ex nihilo*. This conflicts with accepted natural laws. Worse, in some cases, the popping into existence occurs at a time t_d prior to the individual's birth. Even if this is logically coherent, it is arguably quite impossible metaphysically.

Philosophers debate whether a possible phenomenon should be regarded as time travel, as normally understood.[8] Yet it appears from the foregoing that there is a single metaphysically possible phenomenon that may be equally legitimately regarded as time travel or, alternatively, as the de-synchronization of an object's intrinsic clocks with real time, depending only on perspective. Whether one describes the phenomenon in question as a change in real time with respect to proper time, or instead as a change in proper time with respect to real time, in some sense the same facts are captured. The two descriptions are equivalent—two sides of the same coin, six of one and a half-dozen of the other, two inversions of the same chord, two *Sinne* converging on the same *Bedeutung*.

In many contexts, and especially in science fiction, the description in terms of time travel is favored over the other, although the other is generally the less misleading description. With spatial motion—continuous change in position from one spatial location to another over time—the spatial traveler is at the former location at one time and at the latter location at a later time, having traversed a path between the two locations in the interim. This appears to be integral to the very concept of *motion* (*re-location*; *change in position*). If time travel is the temporal analog of spatial relocation, then by analogy the time traveler is at one temporal location t_o at one time t, and at a different temporal location t_d at a time t' subsequent to t. But that much is true of everything that persists from t_o to t_d (or the other way as the case may be), time traveler or no, since t_o and t_d are themselves such a pair of times $<t, t'>$. If something x exists at a time t, then at that very time t, x is at t. There is no more relocation-to-a-different-time occurring with the intrepid time traveler than occurs with the guy flipping burgers at the local eatery. A so-called time traveler may be on proper time, but the traveler persists in real time.

As defined, time travel is not the temporal analog of spatial motion. Talk of 'time travel' relies heavily on shifting from real time to proper time at crucial junctures. We tend to think of proper time simply as time and of the destination time as a different place. These modes of thinking are confused. The destination time is not a place; it is a real time. Proper time is also time, but the so-called time traveler is merely on it. Traveling from a timeline segment beginning with t_o, to another beginning with t_d, the time traveler is at the former timeline segment when on t_o, and at the latter timeline segment when on $t_o + d_p$. But the forward time traveler is still *en route* to t_d when at $t_o + d_p$ and the backward time traveler does not even exist at $t_o + d_p$. In either case the time traveler exists at the corresponding real destination time, t_d, but in either case the time traveler also persists all the while from t_o to t_d, or from t_d to t_o.

Authentic Wellsian time travel requires a more full-blooded, non-metaphorical notion of two-timing. Insofar as spatial motion is relocation in space over time, authentic time travel is relocation in time over time at a rate other than 1. What is

[8]Hilary Putnam in "It Ain't Necessarily So," *The Journal of Philosophy*, 59, 22 (October 25, 1962), at Sect. 4; Robert Weingard, "On Traveling Backward in Time," *Synthese*, 24 (1972), pp. 117–132.

commonly referred to as 'time travel', both in science fiction and in science proper, is *simulated* time travel. The simulation is accomplished by treating real time as space while treating proper time as real time, pretending that the protagonist is at a time that in fact, or within the story, the traveler is merely on, not at. The storyteller or theorist completes the charade by letting the narrative follow proper time instead of (or in addition to) real time, while relegating real time to a kind of spatial dimension rather than temporal. The subject is depicted as changing "temporal location over time." This is not the same thing as the subject's proper time merely being out of sync with real time. In authentic Wellsian time travel there must be two non-overlapping times such that when the time traveler is at one of them, the traveler is not only on but also somehow *at the other*. At real time t_r, the traveler is not only on t_p, by virtue of the traveler's intrinsic clocks being set to t_p, but also somehow *at* t_p *in addition to being at* t_r. At one time the traveler is at two times. But it is unclear what this could be. A new notion of *being at a time* would be required, one that allows for something to be at two non-overlapping times at one of them, and so at one time at a non-overlapping time. But this seems precluded by the very concept and logic of *being at a time*. This fact challenges the very conceptual possibility of Wellsian time travel.