

A TIME-TRAVEL DIALOGUE

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MONDAY

It is a Monday afternoon at the Jefferson National Laboratory particle accelerator facility in Newport News, Virginia. A computer scientist has just arrived to help Dr. Carlene Rufus with her work in particle physics. The computer scientist, William "Willie" Esquire, is a member of the faculty at North Carolina State University. In addition to his Ph.D. in computer science, he has an undergraduate degree in physics and a Ph.D. in philosophy. Willie has a mind for theoretical reasoning and is eager to help Rufus with her latest research. Rufus is a patient, meticulous woman with utter confidence that all problems of the world can be solved if enough accurate data are collected. Her lab assistant, Tad Logan, will soon have his Ph.D. in physics. He has worked with Rufus for a couple of years and knows his way around the lab. They cordially welcome Willie and start to familiarize him with their work.

Dr. Rufus: Tad, will you show Willie to the control console?

Willie: Looks like you are running a pretty powerful system here. You must have two dozen new HP-UX's in here.

Tad: Twenty actually, running about eighty Motorola VME's for input/output control. Coffee?

Willie: No thanks; it's a little late in the day for me and caffeine. Where does the funding for all this equipment come from?

Dr. Rufus: The Department of Energy, primarily, but NASA, the National Science Foundation and a few research universities are also very interested in what we are doing. We may be on the verge of a cutting-edge discovery.

Willie: What sort of discovery?

Tad: A new fundamental particle.

Willie: Really? My particle physics might be a little rusty, but tell me about it anyway. What is this new particle?

Dr. Rufus: We are trying to isolate the very elusive psi-lepton. But we're not sure if we've found *it* or some unanticipated cousin. The particle we are observing behaves exactly according to lepton theory, except for one mysterious characteristic.

Willie: I think I remember reading something about the psi-lepton. Seemed like pretty abstract, speculative stuff to me.

Dr. Rufus: Yes, it is—was, until now. Well, maybe. Most of my colleagues have been very skeptical, which is why we're taking so much care in trying to explain why our particle deviates from the

theory in the way that it does.

Willie: So what's the discrepancy?

Dr. Rufus: I have some graphs to look over and some more calculations to do. Tad, would you please tell Willie about our dilemma and show him where the accelerator-control program files are so he can get to work.

Rufus returns to her office, leaving Willie with Tad who sits down at a terminal near the command console and begins to show Willie the file system.

Tad: Okay. The experiment we're running involves the ultrarelativistic collision of a uranium isotope and a heavy helium ion. We've set up fields to filter out every particle predicted to escape the collision except (in theory) the psi-lepton and we have the software in place to analyze the data from the detection devices in order to track position and energy. It seemed undeniable that we had observed a psi-lepton, except that it vanished long before theory predicts.

Willie: Then your particle has a faster decay rate than it should have?

Tad [*shaking his head*]: Not that simple. After a few more runs with the same result, we decided to look more closely at the last fraction of the particle's life. What we saw was that another particle appeared out of nowhere and annihilated our psi-lepton-like particle.

Willie: Out of nowhere?

Tad: I should be more precise. Studying the early moments of the second particle's appearance we confirmed that it is formed out of *very* small, almost undetectable, energy fluctuations that are present in the accelerator. Such a spontaneous formation process is theoretically possible, but we calculated the probability of it occurring to be on the order of 10^{-800} . So, right now Dr. Rufus is trying to come up with a more plausible explanation for its appearance.

Willie: That's why you've called me? You want to know if there is a fault in the accelerator's program that is giving you these strange results?

Tad: Exactly...Ah, here are the accelerator-program files. You really a philosopher?

Willie: Well, I have a Ph.D. in philosophy. I loved doing metaphysics, but a job was hard to come by.

Tad: I guess you can't really expect Department of Energy funding for that stuff. I'll let you get to work.

Willie begins to study the complex programs that run the accelerator. After a few hours he finishes and approaches Rufus in her office.

Willie: May I?

Dr. Rufus: Certainly, come right in.

Willie enters the office.

Dr. Rufus: Did you find anything?

Willie: Actually, I did. There was a strange glitch. My guess is that there is some kind of hardware problem since I was able to bypass the problem using some alternative code. The new code should be functionally equivalent, but my simulations now run much more smoothly. As far as I can see, the accelerator should work properly now.

Dr. Rufus: Excellent work. Now we can see whether we really have the psi-lepton. It is time to run a new trial. Please stay.

Willie: Thanks. I think I will.

Rufus and Willie leave the office and walk back to the control console.

Dr. Rufus: Tad, Willie thinks we are ready to go. Would you ready the accelerator?

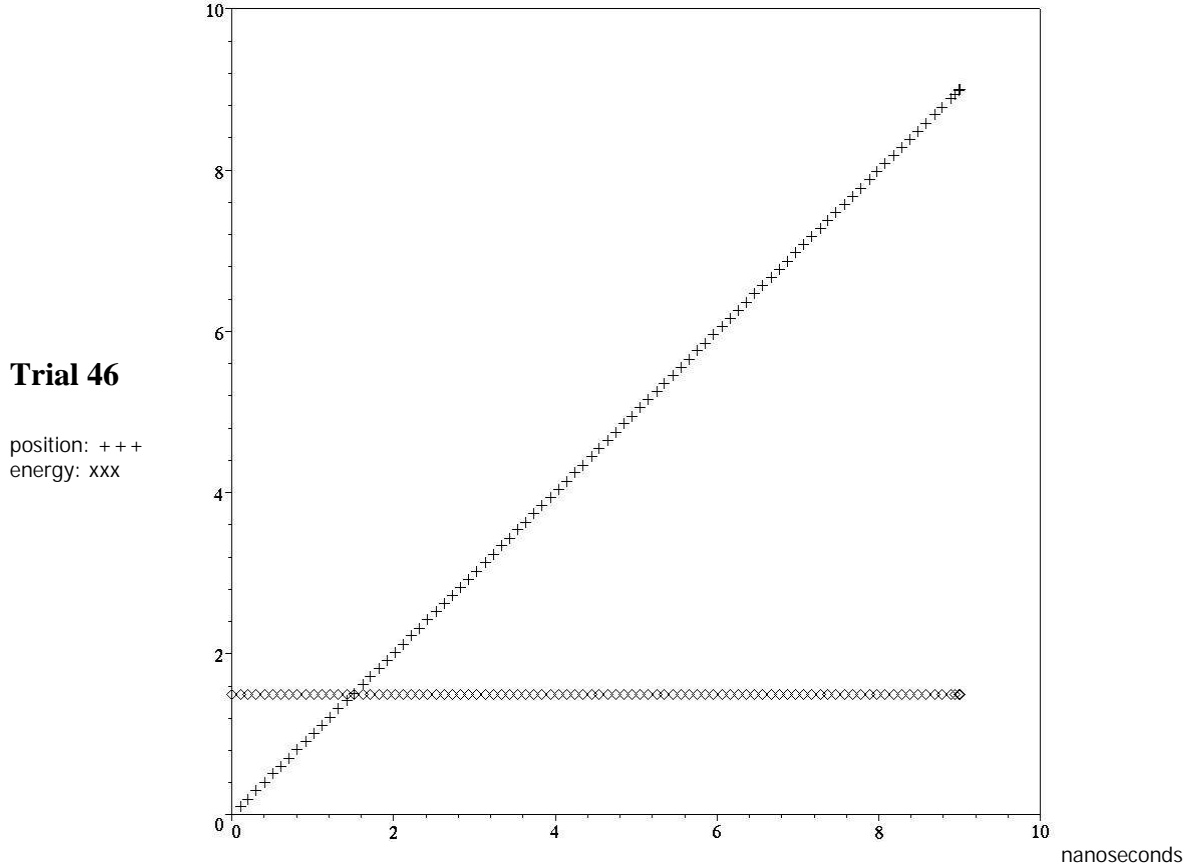
Tad: Gladly!

Tad sits down at the console and enthusiastically punches in the necessary commands.

Tad: All set Professor. Shall I start it?

Dr. Rufus: Go ahead, Tad.

The accelerator starts up with a dull humming sound. In a few minutes, the results from the experiment appear on the monitor and the printer begins to print out several pages of data. Tad tears off one of the sheets and shows it to Rufus. Willie is pleased, but not very interested; he doesn't look at the data.



Tad: Congratulations, Dr. Rufus. You've done it! The data indicate we had a perfectly stable psi-lepton in the detection chamber. This is just what that so-called speculative theory predicts.

Dr. Rufus: Thank you Tad, but don't be hasty. Right now the scientist in me is still curious about what was happening before Willie sidestepped that strange glitch he found. If the particle really was a psi-lepton, how can we account for the strange behavior it exhibited? Willie, do you know how the glitch was affecting the accelerator?

Willie: Not exactly. Like I told you before, I suspect that there is some kind of hardware problem. Some disturbance takes place in the chamber when the program is run with the original code, but not with my rewrite. Without pulling apart all this beautiful equipment, that's about all I can tell you. If it will help, I could probably figure out *when* the glitch takes place by restoring the original program.

Dr. Rufus: That's not very much, but every bit of information is potentially useful.

Willie: Sure, reinserting the original code should only take a second. Then I'll attach a diagnostic log that will show when the glitch kicks in and the disturbance begins.

Willie sits back down at his terminal and types for a minute or two. Rufus takes a seat nearby.

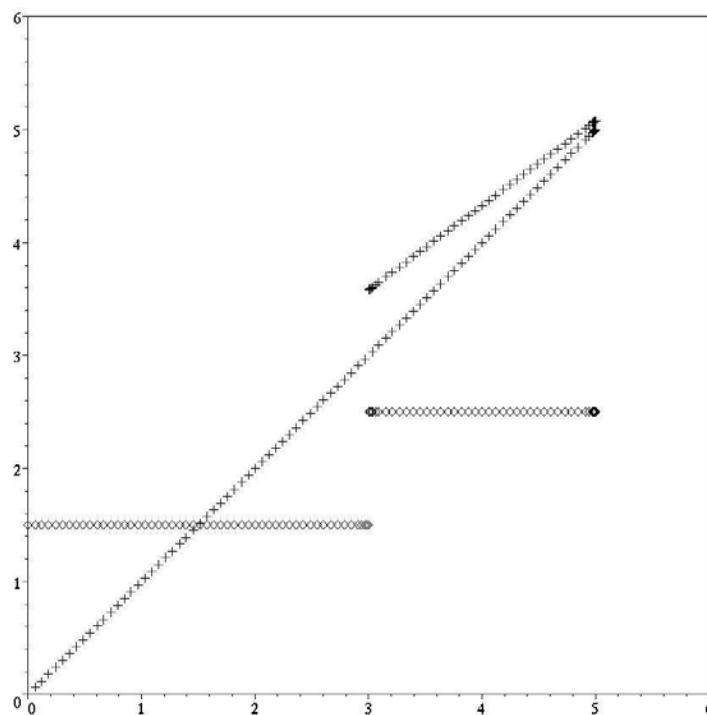
Willie: That should do it.

Dr. Rufus: Thank you. Tad, will you run the creation process again?

Tad [*still excited about the results of the last run*]: One psi-lepton coming right up!

Tad enters the commands again and after a few more minutes the data appear on the control monitor. Rufus and Tad take a look.

Trial 47



Dr. Rufus: The anomalous particle is back. Once again, it originates at $t = 3$ nanoseconds as it did in Trials 1 through 45.

Willie [*not looking up from his terminal*]: I know this is going to sound weird, but the glitch seems to occur after about five nanoseconds.

Tad: That's strange. If Willie is right, the glitch could not have caused the second particle to appear. The origin of the second particle is still a mystery.

Dr. Rufus: Hmm...

Tad: What are you thinking, Professor?

Dr. Rufus: In contrast to what you said, Tad, if the glitch is not present, then the anomalous particle does not appear. When it is present, the particle does appear. So, the glitch does seem to cause the second particle.

Willie: Backwards causation?

Tad: What?! You're not serious, Professor.

Dr. Rufus: It's the closest thing to an explanation for the appearance of that particle we've come up with so far. Why couldn't it be a case of backwards causation?

Tad: Because that's ludicrous! Something in the future can't cause things in the present or past to occur. That's just the paradoxical kind of thing Hollywood takes up, not serious researchers.

Rufus raises her eyebrows in mock offense, but just tears off a graphical printout of the latest trial and starts jotting down some notes, not saying a thing.

Willie: What Hollywood seems to care about is entertaining and lucrative time-travel plots. (And, by the way, philosophers anyway do think about backwards causation and time travel a fair bit.) You should be careful to keep backward causation distinct from time travel. Time travel to the future doesn't require backward causation at all, and backwards causation can happen without time travel. Dr. Rufus's hypothesis, if I've got it right, states that the glitch causes the anomalous particle to appear at an earlier time than the time of the glitch and then the new particle moves off and collides with the psi-lepton. No time travel.

Tad: Fine, but this still doesn't make sense. The problems that come up in the time-travel movies arise not so much from their time-travel aspect but from the presence of backward causation. Take *Back to the Future*, for instance. Doc sets the time controls of the Delorian in 1985, and Biff gets covered in manure in 1955. The former event—the later one—caused the latter event—the earlier one: time travel plus backward causation. Okay so far, but consider this. Say Marty time travels to the past and breaks up his parents' meeting, which he only does temporarily in the movie. If he had done so for good, he would no longer exist to affect those events he just caused. If he didn't exist, then he would never have gone back in time to break up his parents meeting in the first place. It doesn't take long to find absurdities here.

Willie: I'll grant you that most time-travel movies are absurd, but that's because screenwriters don't have philosophy degrees. The absurdities occur because everyone is worried about dramatic effect rather than logic. The problems in these movies do not undermine the possibility of either time travel or backward causation. There are other movies that are logical. *Terminator* is one.

Dr. Rufus: I am afraid I am not familiar with that film.

Willie: In the movie, our society of the future is destroyed by cyborgs that were created by a company called Skynet. A devastating war between the machines and the humans takes place. During this war with the machines, the technology for a time displacement machine is discovered. As events unfold, one man and one terminator are sent backwards in time. The terminator is programmed to kill Sarah Conner, the mother of the leader of the human rebels, which will in effect kill her unborn son, John Conner.

Tad: Okay, you explain *Terminator 2*. How are all the characters unchanged after they destroy the terminator's hand and microchip?

Willie: Yes, well, the second movie is not consistent. This time two cyborgs are sent back from the future, one to kill John Conner, now a teenager, and the other to protect him. Meanwhile, Sarah decides to try to kill the genius behind Skynet, the company destined to create the first cyborg technology.

Tad: Something that would change events drastically for the future, if she succeeds.

Willie: Yes, and she does at least convince him of the destruction his new technology will cause; together they go to demolish the Skynet headquarters.

Tad: In effect, causing the cyborgs not to be created, or the time machine, or John.

Willie: Right. We learn that the reason Skynet was able to construct its first cyborg machine was because it found and studied the parts that were left intact—the hand and the microchip—when the terminator of the first movie was destroyed. So the original movie could not have happened: no war, no time displacement unit, and no cyborg machine. Fun stuff, but not entirely coherent I'm afraid. So I concede to you that *Terminator 2* is a mess. I would, however, like to suggest that the first *Terminator* lacked any contradictions.

Tad: How's that?

Willie: A terminator goes back in time set to kill a young Sarah Conner. I don't see any logical fault in that.

Tad: Yeah, but killing Sarah Connor would drastically change the future. Her son would never have been born and would never have fought the cyborgs, which the movie tells us he did. It would seem we would have a dilemma. The cyborgs' future existence would then be dependent on her existence.

Willie: But the terminator wasn't successful. He didn't kill Sarah Conner. There is no suggestion that something did and didn't happen at the same time. In *Terminator 2*, however, it had to be both true and not true that Skynet developed cyborg technology; so there was a contradiction. It seems to me that as long as there is no hint that at one and the same time something both did and didn't happen, then the stories are consistent.

Dr. Rufus [*Looking up from her work*]: I am going to have to cut this off; I want to get back to what is going on with the psi-lepton, if that's what it is.

Willie: May I have a look at the printout?

Dr. Rufus: Certainly, here's the graphical record of the last trial.

Rufus hands Willie the graph for Trial 47.

Willie: I know I'm rusty, but doesn't that indicate decay?

Tad: No, the time-axis runs left to right this way [*gestures*]; you're looking at it from the wrong direction.

Dr. Rufus: Wait a minute, Tad. Willie's right. That's what I wanted to show you. The plot of the anomalous particle looks much more like a decay process than a creation process.

Tad: Interesting, we have a creation that looks like a backwards decay, but so what?

Dr. Rufus: You should not be so quick to ignore your own thoughts. Weren't you the one, a few minutes ago, who brought up the idea of time travel?

Tad: Yes, but only to make fun of...

Willie [*interrupting*]: Are you saying that this particle is time traveling?

Dr. Rufus: I think it's a candidate explanation for what we are observing. Wouldn't you agree, Tad?

Tad: I don't know—a time-traveling psi-lepton?

Dr. Rufus: Time travel could explain all of the strange data we have collected. Willie said the glitch happened at nearly the exact moment that the two particles collide, but the data show no residuals from a collision; both particles just vanish. What if there was only one particle? The glitch could have caused the psi-lepton to reverse its temporal direction. At that point the psi-lepton ceases traveling from present to future and begins traveling from present to past. The two particles we see could be the psi-lepton traveling forward in time, and the *same* psi-lepton traveling backwards in time.

Willie: I am not sure that I follow. How is the lack of residuals relevant?

Dr. Rufus: The diamond plot on the graph tracks the energy of the system. Notice that there is an increase when the anomalous particle appears. What is peculiar is that there is no increase in energy after the supposed collision, no residuals of the particle annihilation. In fact, the energy drops immediately to zero.

Willie: But, if the glitch caused the particle to turn around in time, so there was no annihilation, we would have an explanation for the lack of residuals and for the origin of the second particle! Wow, we might have just witnessed a case of backwards time travel.

Tad: Oh, come off it Willie! That doesn't mean anything. *Terminator* notwithstanding, time travel is a fantasy. It would generate all these crazy, impossible situations. I could go back in time and shoot my grandfather. But then if I shot my grandfather, I wouldn't exist, because my grandfather would never have fathered my father and my father would never have fathered me. But then you'd have my grandfather lying dead in the street back in 1930, and his killer would never have existed. That is impossible.

Willie: What you're talking about sounds a lot like the *Back to the Future* scenario, except more problematic.

Dr. Rufus: If the particle is not time traveling, how do you explain the fact that the program glitch seems to cause the second particle to appear and that its appearance looks much more like a decaying process than a creation process?

Tad: I don't know; perhaps it's just a freak coincidence.

Dr. Rufus: Not just one freak coincidence, Tad, lots of them. We have run this experiment 47 times in the last month and every time, excluding the one time when we ran it without the glitch, a second particle has appeared.

Willie: Yes, if you're content to dismiss anomalies as coincidences then I don't see how you could make progress in science. At least the time-travel hypothesis explains away the coincidences.

Tad: But...

Dr. Rufus: Look fellows, this talk really won't get us as far as more lab work will. We need to run more tests tomorrow. You don't mind returning tomorrow do you Willie? We may need you to remove and restore the glitch a few more times.

Willie: Sure, I don't have any pressing projects, and I think the Department of Energy can afford me.

Dr. Rufus: Then I'll see you two tomorrow. Don't forget to lock up, Tad.

would appear to explain the lack of residual energy after the time-reversal and the origin of what we thought was an anomalous second psi-lepton-like particle.

Dr. Rufus: That's fair enough.

Tad: Okay, but I have a question about the supposed explanation of the origin of the second particle. Admittedly, according to the hypothesis, its *origin* is no longer a mystery; we created it when we banged the uranium off the helium. It is the psi-lepton. But, we still don't have an explanation of what is going on with that particle at $t = 3$. That's what was really bothering us; that's what was highly improbable by your calculations and yet was happening over and over again. So what if that isn't the origin of that particle? According to the time-travel hypothesis, it is the time-reversed decay of the particle. Fine, I'll go along with that. But, I don't see that we have an explanation for *why* it decays.

Dr. Rufus: Excellent, Tad. Quite perceptive.

Tad: Yesterday, we thought the time-travel hypothesis would account for the origin of the anomalous particle. In a way, it says that it doesn't originate, at least not at $t = 3$. Very neat, but if we are taking this idea seriously, there is still something here that needs to be explained. In your version, Professor, the anomalous particle isn't coming into existence at $t = 3$ —it is beginning the reversed decay. But why should it do that?

Dr. Rufus: It did not occur to me until late last night, but I think that my hypothesis predicts the decay too. Take a look at the "lifespan" of the particle in Trial 47. It originates at $t = 0$, behaves normally until $t = 5$, and then travels backward in time for two additional nanoseconds. Its lifespan until it decays, how long it is around from its perspective, is seven nanoseconds.

Tad: So?

Dr. Rufus: Seven nanoseconds is precisely what theory predicts for the lifetime of a psi-lepton. It is also exactly how long our normal psi-lepton lasted in Trial 46.

Tad: Clever, but I still don't know...

Dr. Rufus: None of us knows much of anything at this point, I'm afraid. We really are doing little more than speculating. What we need is more tests.

Willie: Maybe it would help to think about how the time-travel hypothesis we are considering differs from the idea of backward causation that you first floated. There is a big difference. Yes, the glitch seems to have some kind of backwards causal connection with the existence of the anomalous particle at $t = 3$. It would be amazing if we could confirm even that much. But, if the anomalous particle is the psi-lepton time traveling, then the "two" particles that the detector is picking up are really one. That really is crucial to the time-travel hypothesis. It's what takes the issue of the origin

of the anomalous particle out of play. It also has some more fantastic-sounding consequences. It implies, for example, that the psi-lepton was at two different places at one time.

Tad: You're the philosopher. You figure it out. That there is really only one particle doesn't seem like such a big deal. Their sameness is easy enough to swallow. All I know is that there's no observable difference; according to the data from the detectors, they're the same. If they're in different places at the same time, no big deal. It's the whole problem of something in the future causing things in the past that bothers me; whether it's the same particle seems trivial by comparison.

Willie: The issue is not whether they share the same qualities, because many things share qualities and are not the same thing. I mean, simply because my apple is red and my son's ball is red does not entail they are the same object. Or, even if your son has a ball that is red with the same diameter and texture as my son's ball, they are certainly not the same ball.

Tad: I don't have a son.

Willie [*exasperated*]: That's irrelevant, I am only...

Tad: Just messing with you. I see what you're trying to say about the balls, but psi-leptons are much different than mass-produced children's toys.

Willie: True, but qualitative agreement is still no guarantee of numerical identity whether we are talking about the quantum or the macroscopic world. Say you entered a building yesterday and saw different colored chairs in a room and you sat in one of those chairs. Overnight, the chairs are shifted around, stripped of their paint, and then repainted. Let's say the red ones were stripped and painted blue and the blue ones stripped and painted red. If you didn't know this had happened, you might see a chair today with the same color, shape and weight as the one you sat in the day before. Because the chairs had been painted, this wouldn't be the same chair as the one you sat in the day before, but yet, it has the same qualities. What makes the chair you took notice of today the very same thing as the one you sat in yesterday?

Tad: Well there's a history to the chair. It was as I saw it yesterday. Then, someone moved it, stripped it, painted it, set it aside to dry, and then it was as I saw it today. There's a sequence of events and if you follow the chain, you can tell which is which. But no one is painting our particle.

Willie: True. It also helps that we can follow the path of the particle.

Dr. Rufus: Good idea, Willie. Let's drop the metaphysics for a moment and concentrate on what we really know about this particle's life. The path on the bottom of our second graph from yesterday, Trial 47, is the theoretically predicted path of the psi-lepton. At all the relevant layers in the detection chamber, it behaves exactly as predicted by my calculations. You can see here [*pulling a stack of data printouts out of a folder*] that in each of our trials the mass-energy, momentum, charge and spin for this path have exactly the predicted values, until, that is, the unexplained event occurs.

Tad [*interrupting*]: You mean the collision?

Dr. Rufus: I won't call it a collision or a time-reversal yet. The point here is that, according to the data, we have a perfectly stable psi-lepton right up until the time of the event. Now, the path on the top, here, is where the confusion is coming from. As Willie pointed out yesterday, it looks very much like the particle is a decaying psi-lepton, provided that you reverse the time-axis. Indeed, all of the data indicate that it is a psi-lepton. I don't, however, want to be too quick in saying that it is displaying all of the features of decay. So, this morning I am going to try to see how much water that hypothesis will hold by running a computer simulation of the theoretical psi-lepton with time reversed and compare it to the data we have here.

Willie: But even a perfect match won't establish the time-travel hypothesis. I am not sure what would decide it. There would still be a number of unanswered questions and untested theories. For example, even if the simulation matches the data perfectly, that doesn't give us proof that the "two" particles are the same particle. It could still be two forward-in-time particles colliding or even a forward-in-time particle creating a brand new backwards-in-time particle.

Dr. Rufus: Right. This is just a starting point, but if the computer simulation does not show the same time-reversed behavior then we will have at least a little more reason to think twice about the time-travel hypothesis.

Willie: I guess so. That certainly sounds like something worth checking. But, regardless of what the simulation shows, we still have the problem of explaining what's going on during *the event*, as you called it.

Tad: A few minutes ago we were talking about the identity and continuity of our particle. It seems to me if we could somehow verify that the two particles we are observing are actually just one particle then we'd have good reason to conclude that what is happening here is really time travel.

Willie: Right, but I don't see how we could go about it. We have seen that both particles display all of the detectable psi-lepton properties; they both have the right mass-energy, charge and spin, but the two particles having the same properties isn't enough evidence to call them identical. What I was getting at before is that we also would want to establish an uninterrupted spatiotemporal and causal continuity between the psi-lepton on the bottom of our graph and the psi-lepton-like particle up on the top. But, what is amazing is that, even though there is such a continuity, that doesn't decide whether it is two ordinary particles colliding, one ordinary particle producing a new time-traveling particle, or really our time-traveling psi-lepton turning around in time.

Tad: Well, I don't think it is unreasonable to say that we have the continuity for the path on the top and the path on the bottom separately, if we can't say that then I think experimental physics in general turns out to be pretty useless.

Willie: Yes, but that doesn't even tell us which direction the causation is flowing. Is it forward causation or backwards causation? We're also left with the problem of explaining what is going on

during the event. We need to find some way to establish a direct and continuous causal connection from the particle on the bottom an instant before the event to the particle on the top an instant before the event. Then we need to find some reason to think they are the same particle, not one particle producing a qualitatively similar new one.

Tad: Well, given our data, even I have to admit that doesn't seem like too much of a stretch. If we push your concern to its logical conclusion, how can I even say that this coffee cup is the same as the one I took out of my cabinet this morning. Maybe there was a new one instantaneously produced moments ago.

Dr. Rufus: I agree, Tad. Look fellows, we have a hypothesis here, the time-travel hypothesis, that appears to explain some highly unusual data. I am not going to reject it based on this philosophizing. We may not be able to *prove* that it is a single psi-lepton, but that's just science for you. I am not a mathematician or a philosopher. I am not looking for proofs. In any case, I still can't believe, Willie, that you would abandon our hypothesis, a seemingly explanatory hypothesis, based on these philosophical worries about identity.

Willie: I am not sure I would, but, look, the explanatory promise of the time-travel hypothesis won't distinguish it from some competing hypotheses. Here is an equally explanatory hypothesis: backwards causation but no identity. Psi-lepton and the glitch work together to produce a brand new time-traveling particle.

Dr. Rufus: Perhaps that hypothesis is equally explanatory, perhaps not. My hypothesis seems a good bit simpler. Your competing hypothesis must be that the state of the psi-lepton causes a new particle to come into existence during the event with all the same properties as the psi-lepton. Mine is that the psi-lepton time reverses. Mine seems easier to state and posits fewer particles. The account of the missing residuals also seems more natural with my hypothesis. We don't have to worry about the sudden decay of one particle, the immediate creation of a new particle, and whatever kind of energy that would involve. We just have a particle that time-reverses.

Willie: But...

Dr. Rufus [*interrupting*]: That's enough brainstorming for me. We are not getting any closer to trying a new experiment. While I'm working on this simulation, I'd like you two gentlemen to try to come up with some possible ways to manipulate our experimental set up that might give us some more useful data to compare with our previous results.

As Rufus returns to her office, Willie gets up and pours himself another cup of coffee.

Willie: Any ideas?

Tad: Well, like I said before, what was really keeping me up last night was the hypothesis that the glitch seems to be causing the particle on the right here to appear. Even if the particle is time-

traveling, it seems a little weird that the cause of the second particle's appearance happens after that particle appears.

Willie: You're right, that is a big problem, one that philosophers have been grappling with for half a century, at least. If we could find experimental evidence proving backwards causation, you could bet that it would send a shockwave through the philosophical world.

Tad: I bet. The big question is how. Is there some way that we can stop the glitch after the second particle appears? It seems like it might be tough given that there are only a couple of nanoseconds before the glitch kicks in.

Willie: That's an interesting possibility. It might be feasible. It would take some tricky programming to optimize the processor's resources and even then it would be a close call, but I might be able to.

Tad: It seems that if we had time to stop the glitch, we wouldn't really be able to, since according to the time-travel hypothesis, the effect of the glitch already exists before the glitch happens. If we do stop the glitch, we can rule out time travel and backwards causation as possible explanations for the second particle.

Willie: And, if we don't stop the glitch, we will at least still have a lot to talk about. Arguably, we would also have some experimental evidence that backwards causation is happening.

Tad: I'll let you get to work. I'm going to go make sure this is how Dr. Rufus wants to proceed.

Tad walks off to Rufus's office and Willie makes his way towards the terminal he has been using. The rest of the day the three are engaged in their private tasks, thinking about the implications of their possible discovery.

WEDNESDAY

Rufus is already at the lab and working when Tad and Willie arrive...

Dr. Rufus: Good morning gentlemen. Tad, Willie e-mailed me about your idea for removing the glitch after the second particle appears. I think that would be a great way to proceed. If we can stop the glitch from occurring after the second particle appears, we would certainly have to consider that a strike against backward causation and our general time-travel hypothesis. How far did you get yesterday?

Willie: I got off to a good start. I should be able to have the program ready for trials today.

Dr. Rufus: Excellent. Let me know when you're ready. I'll be in my office.

Rufus leaves Tad and Willie in the lab.

Tad: I was thinking about the basis of today's revisions to the program. It seems to me that we don't even need today's experiment to disprove the possibility of backwards causation.

Willie: How did you arrive at that conclusion?

Tad: Well, we already know how to change whether the second particle appears by removing or replacing the glitch in the programming. Furthermore, we know that we *can* remove the glitch after the second particle appears. There is the matter of optimizing the use of the computer's resources to allow us to remove the glitch in the time between the appearance of the second particle and the annihilation of both particles. But, that's just a technological problem, one that you are working on. Even if you don't succeed, we still know it *could* be removed somehow. So, assuming that backwards causation *is* at work, we can prevent the cause of the second particle's appearance after it has already appeared. That can't happen, so backward causation isn't at work.

Willie: So, you reason like this. If the presence of the psi-lepton and the glitch caused the second particle's presence at an earlier time, then it is possible to prevent the second particle's presence at the earlier time by preventing either the glitch or the psi-lepton.

Tad: Right. That's what I said.

Willie: Hold on. There's more. If the second particle's appearance precedes the occurrence of the glitch, which of course it does, then, it is possible to prevent the glitch after the second particle appears.

Tad: That seems undeniable.

Willie: But, it is not possible to prevent the appearance of the second particle after it has appeared. Therefore, it is not the case that the occurrence of the glitch causes the second particle to appear at the earlier time.

Tad: Then, logically, it seems that backwards causation cannot be the case and therefore this particle isn't time traveling. So, what's the point of the experiment?

Willie: Well, the time-travel/backward-causation hypothesis might be false, but your argument doesn't show that.

Tad: What do you mean?

Willie: It's an invalid argument. Let me use another example to show you what I mean. It is possible that my coffee mug is full right now. It is possible that my coffee mug is empty right now. Therefore, it is possible that my coffee mug is both full and empty right now.

Tad: Which is it?

Willie: What? Oh. It's empty.

Tad: Hang on, I'll get you some more.

Willie hands his mug to Tad who goes across the lab to get some more coffee. Tad sees that Rufus is still reviewing her notes. Meanwhile, Willie begins working on revisions to the accelerator program for the day's experiments.

Tad: How's it going, Professor?

Dr. Rufus: I really think today's experiments are going to go a long way towards proving or disproving our time-travel hypothesis. How's Willie coming along with the program revisions?

Tad: He's getting there. He should be ready by early this afternoon.

Dr. Rufus: Until then, I'm going to go continue working on a simulation of the time-reversed decay.

Tad returns to where Willie is working and hands him another mug of coffee.

Tad: I was just thinking about the coffee example. It *is* impossible for the mug to be full right now and empty right now; that really is illogical. But, isn't saying that it is possible that it is full right now and empty right now the same as saying that it's possible that it's full right now and possible that it's not full right now?

Willie: It's tempting to interpret it that way. That's why your argument seems to refute backwards causation. But this example shows that the two are not equivalent. You agreed that it is possible that

the mug is full right now and that it is possible that the mug is empty right now. Yet you also agree that it is perfectly obvious that it is not possible that the mug is both full and empty right now.

Tad: I see. So you think we need to run the experiment?

Willie: Absolutely. First, Rufus isn't going to miss a chance for more data, especially based on a philosophical argument—one of yours or one of mine. Second, yes, we really need to see if the anomalous particle would exist without the glitch.

All three go off to their own tasks. After a lunch break, they reconvene to begin experimenting with Willie's revision to the accelerator program.

Dr. Rufus: Gentlemen, we're ready to set up for today's experiment. Willie, you're sure you have the accelerator program set to remove the glitch as soon as it detects the presence of a second particle?

Willie: Yes, I was able to optimize the use of the processor so that the removal of the glitch can be accomplished in less time than the interval between the annihilation event and the appearance of the second particle.

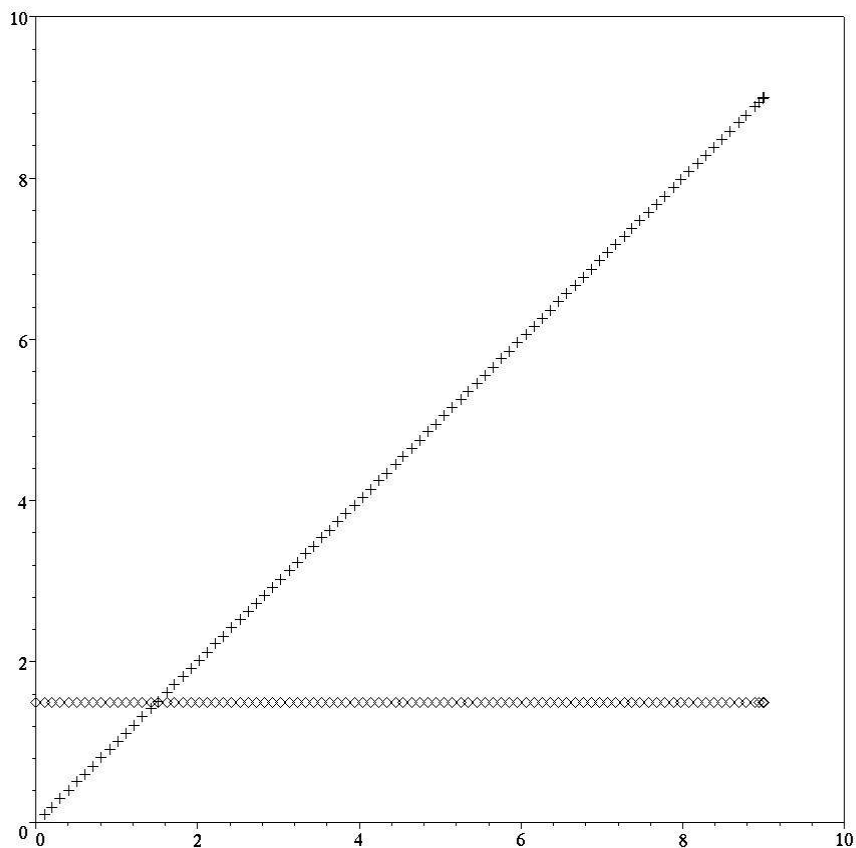
Dr. Rufus: Very well. Shall we continue?

Tad: Certainly. I'm starting the accelerator now.

A few minutes later, data appear on the monitor and the printer. Rufus examines the data for a moment, then a wave of puzzlement passes across her face.

Tad: What is it Professor? What do the data show?

Dr. Rufus: These data look just like the results when we removed the glitch altogether. The second particle never appeared; at least it was never detected.

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Willie: That's strange; the program records show that the glitch was removed upon detection of a particle in the chamber.

Tad: Isn't that just what it was supposed to do?

Willie: Yes. So why don't we see evidence of the second particle?

Dr. Rufus: Hang on a second. Willie, you said your program removed the glitch as soon as it detected *a* particle, right?

Willie: Yes.

Dr. Rufus: At what time did that happen?

Willie: *Looking through the computer records.* The program removed the glitch at time $t = 0.13$.

Dr. Rufus: Hmm... That is moments after the datum showing the creation of the psi-lepton.

Willie: Aagh, I think I know what happened. When I redesigned the program, I set it to turn off the glitch when it detected any particle in the chamber. So, when the psi-lepton showed up, the computer removed the glitch. In effect, we just repeated our experiment from yesterday with no glitch at all.

Dr. Rufus: That would certainly explain these results, but it really doesn't bring us any closer to confirming or disconfirming our time-travel hypothesis. Do you think you can modify the program again so this it really won't turn off the glitch until *after* the anomalous particle appears?

Willie: Yes, I can do it. However, it is going to take a while—the better part of a day. I'll need to make the program sensitive to the total energy in the chamber and set the threshold high enough to prevent unexpected removal of the glitch.

Dr. Rufus: Here's what we can do. Tad, I assume you wouldn't mind a break from our experiment to get a little work done on your own thesis. And, I could use the time to work on my decay simulation. So, we won't perform any trials tomorrow. There is a luncheon that JNL is hosting that Tad and I need to attend. Willie why don't you join us; it will give us a chance to touch base and be ready for the following day.

Willie: That sounds good to me.

Tad: To me too.

Dr. Rufus: Great. It's been a long day already, so let's just shut everything down. We won't be running any experiments until at least the day after tomorrow.

They proceed to shut down the equipment in the lab. It doesn't take long for Tad to raise a question.

Tad: You know, I'm still having problems with the whole time-travel idea. Despite the evidence and the philosophy, I can't help feeling that this whole thing is foolish. It just isn't possible. You can't change the past, so you can't time travel.

Dr. Rufus: I agree with you that we can't change the past, but I fail to see how that makes time travel impossible.

Tad: It seems obvious to me. If you time travel, you can change the past. But, since it's not possible to change the past, you can't time travel. That seems like straightforward logic to me.

Dr. Rufus: And how could a time traveler change the past?

Tad: Lots of ways. In fact, I don't see how in going back to the past one can possibly avoid changing history. What if I really didn't like my grandfather (I actually loved him to death, but just consider the possibility) and I wish I could have killed him. Unfortunately for me, he died before I had the chance. So, I decide to go back in time to kill him before he even met my grandmother. Now, I only

get one shot at going back in time, so I want to make sure I can kill him, so I take all of the latest weaponry with me.

Willie: Hmm...this is sounding like a familiar argument. Keep going Tad.

Tad: Since I have the best possible arsenal, along with advance knowledge of my grandfather's whereabouts, it seems obvious that I can kill him.

Dr. Rufus: Well, maybe you miss, or something else random like that.

Tad: But it doesn't even have to be anything as dramatic as killing my grandfather. I could step on a beetle or crush a blade of grass; even just my presence could *slightly* alter the flow of air, resulting in tempestuous weather changes. To me it seems impossible that I time travel to the past *without* altering the past. If nothing else, my tiny mass would slightly perturb the space-time continuum, resulting in some sort of change in the timeline. Since it is impossible to change the past, it seems that I can't possibly time travel and neither can our psi-lepton.

Willie: Tad, you're saying that you could kill your grandfather because you have all the prerequisites to do so, but that you cannot kill him because doing so would change the past, and you claim that this apparent contradiction rules out the possibility of time travel.

Tad: Exactly.

Willie: Now let's take another example. Let's say that I am carrying a lot of groceries home, and I come up to the door. I then say, 'Could you get this for me? I can't open the door'. Yet I very well *could* open the door. I've done it hundreds of times.

Tad: How is that at all like my example?

Dr. Rufus: I think I see how they are similar. Willie, with only his normal abilities, could not get through the locked door while carrying a full load of groceries; yet, Willie can get through the door when he isn't so burdened or if he had extraordinary abilities. In your example, Tad, we might say it is possible for you to kill your grandfather if we hadn't taken into account the fact that he died of some other cause at a later time and was your grandfather and everything else. It might even be true to say you could kill him. But, relative to all those things we do know about the case, no, you can't.

Tad: It seems to me that you are using some kind of weird definition of 'can'. I just mean 'can', as in 'possible'.

Willie: Dr. Rufus is right. When you say, 'x can't happen', you normally don't just mean that there is absolutely no possible world in which *x* happens. There are possible worlds where even the laws of physics don't hold and so we'd almost never use the word, 'can't'. How 'can't' actually works is to indicate that there is no possible world where *x* occurs and certain other facts hold. What facts depends on the features of the conversation we are in.

Tad: All right, so what if ‘can’t’ means that there is no possible world where the event occurs and certain other facts hold. I still both can and cannot kill my grandfather.

Dr. Rufus: I don’t think so. There is a sense in which you can and a sense in which you can’t depending on what facts are taken as given. You can kill your grandfather given the fact that you are well-armed, not taking into account how he actually died of some other cause. On the other hand, you obviously cannot kill him, given the fact that you didn’t kill him and that he died a few years ago of cancer. It doesn’t even matter if it is you who is trying to kill your grandfather; the same limitations apply for anyone else that goes back in time.

Willie: Your scenario doesn’t contain a contradiction, Tad. It would only be a problem if you could and could not kill him given the same facts held fixed. That’s not the case. There is a kind of equivocation.

Tad: But when I step out of my time-machine and bend that blade of grass, I have changed the past!

Dr. Rufus: I disagree. You caused the blade of grass to be bent, but that’s not changing the past unless in the past, at that time, the blade wasn’t bent.

Willie: And, in fact, it was bent if your story is going to be consistent. Don’t try telling us that it was straight as an arrow at that time the first time that time happened, but was bent the second time that time happened. That really is a contradictory story, but there is no reason to think that all time travel is like that. That grass was already bent.

Tad: Well, if we can’t change the past what were those cyborgs thinking about in the first *Terminator*—the one you think is consistent—when they sent the terminator back to kill Sarah Conner?

Willie: That is one thing I didn’t like about that movie. I still think there is no contradiction, but the cyborgs do reason poorly in thinking they can prevent something they know to have happened. It is unfortunate that this provides the basic premise for the whole rest of the story. It is a rare time-travel movie that acknowledges our inability to change the past, though there is the sci-fi gem *12 Monkeys*.

Tad: What happens in it?

Willie: A man, James Cole, backward time travels. He is sent back from 2035 to determine the origins of a deadly virus which plagued humanity in the year 1996, and drove the survivors underground. His goal is to take a sample of the pure virus to the future for study, so that a vaccine might be discovered.

Tad: But if the vaccine is discovered, then the deaths of 1996 could be prevented after they occur, which leads to a contradiction...

Willie [*interrupting*]: ...Hold on. That's not what he was up to. The scientists knew he couldn't save those who were already dead. The scientists want to make a vaccine to prevent further deaths and allow people to reinhabit the surface of the Earth.

Tad: I think I understand enough, though it is now starting to sound like I would *have* to step on that blade of grass as I step out of my time machine, which is crazy.

Willie: Why is that crazy?

Tad: Presumably there wouldn't be anyone there to grab my foot and push it down on that blade of grass. No one and no thing would be forcing me to step on that grass. So, how could it be true that I would *have* to step on that grass? If that blade of grass had to be bent, it is not even clear to me how I could have caused it to be bent. It sounds like it would have been bent no matter what I did.

Willie: The language is tricky here too. When we say, 'It would have to be bent' or 'You would have to step on it', we are taking for granted that you did step. We are saying something pretty trivial that, necessarily, if you did step on it, then you would step on it. We can just as easily say that, necessarily, if the blade of grass was bent, then no matter what you do the grass would be bent. But, so what? These are really trivial claims.

Tad: But I wouldn't have to! No one would be forcing me! I could decide to *hop* out of my time machine rather than step down and miss that blade of grass completely.

Willie: Of course, you could.

Dr. Rufus: Wait Willie. It sounds like you are contradicting yourself. Which is it? Could he have hopped out of the machine or not?

Willie: Like I said, this is tricky. Don't forget about my trouble carrying the groceries. Could I have opened that door or not? A simple question to answer when it is clear what is being taken for granted. I surely said something true when I yelled for help and said, 'I can't open the door'. It was a very natural thing to say. But, sure, there are other conversation where it would true to say, 'I could have opened the door'. After all, all I would have needed was slightly longer arms and a touch more upper body strength. So, you ask: 'Could Tad have hopped out of the machine or not?'. It's a hard question to answer when it is not clear what is being taken as given. If we hold fixed that Tad did step on that grass thirty years ago on that date, that he did step down and not hop out of the time machine, then yes he had to step down as he did and no he couldn't have hopped out of the machine. If we don't hold that fixed, if all we are holding fixed, say, is that Tad at the time has the normal allotment of physical capacities and that there is nothing coercing him to do what he did, then sure he could have done lots of other things. He might have decided that the 1970's looked kind of scary and never left the time machine.

Tad: I think I understand enough, though it is now starting to sound like there is no fact of the matter about what I would be able to do. [*Willie is about to reply, when Tad continues.*] Hold it. Don't say

a thing. I am too tired to keep this up. My head is starting to hurt. Professor, am I right in thinking that we are about done here? If so, I'm going to head home.

Dr. Rufus: That sounds like a good idea. I'll see both of you at the luncheon tomorrow.

THURSDAY

Rufus, Willie, and Tad are all seated at a table. The introductory speaker, Dr. Twitchell, has just concluded a talk concerning the expanding universe, and the lunch is being served.

Dr. Rufus: It looks like we will be gathering a lot more data concerning our mystery particle in the coming weeks. I'm really intrigued by the possibility that it could be time traveling.

Willie: Me too, but I'm still thinking about Dr. Twitchell's talk. It has always struck me as odd to describe the universe as expanding. What is it expanding *into*?

Rufus and Tad roll their eyes, sarcastically.

Tad: I don't know about that Willie, but something similar has been bothering me about our time-travel hypothesis. I am wondering where our particle could go.

Dr. Rufus: I do not understand.

Tad: If the psi-lepton reverses its direction in time, not being annihilated in the present but traveling from the present to the past, then we should acknowledge that a time other than the present exists. But, that's not right. You see, what happened yesterday, or even a moment ago, is done. It happened in another time, and that time no longer exists. This is now and the past and future don't exist. How can the psi-lepton time travel if there is nowhere for it to go?

Rufus takes on a mildly interested expression while Willie looks as though he has heard such an argument before.

Willie: Tad, that sounds just like some arguments against time travel that I've heard from proponents of *presentism*.

Tad: What is presentism?

Willie: Well, although it is defined somewhat differently among philosophers, presentism is generally taken to hold that only present things exist.

Tad: Okay, that seems pretty obvious to me, but I get the feeling that there isn't general agreement that that's the way the world works.

Willie: You're right. Many philosophers believe in some form of *eternalism*. It is rather like the opposite of presentism; it holds that some non-present things exist. Eternalists are fond of treating time like a fourth dimension of space. Future times and past times exist just as distant regions of space do.

Tad: I don't get it. You are saying that a presentist would claim that Albert Einstein does not exist, which is obvious to me, but would an eternalist claim that Albert Einstein does exist?

Willie: Yes, but the eternalist would concede that he doesn't exist *now*.

Tad: Wait, that also doesn't make any sense to me. How can you claim that something exists, but that it does not exist now?

Willie: Well, I'm not claiming that, but an eternalist might say that that particular something does exist, not in the present, but in the past.

The server brings three lunches.

Dr. Rufus: Actually, it seems obvious to me that Einstein does exist—not now but in, say, 1905. We are talking about him after all. Willie, I guess you would classify me as an eternalist. But, I am wondering, wouldn't the presentist admit that as well? I mean, wouldn't he concede that Albert Einstein doesn't exist now but does in 1905?

Willie: Ah, strictly speaking, no. You have pointed out a key difference between the presentist and eternalist, though. The eternalist might say that Einstein *exists* some years ago, but the presentist would only say that he *existed* some years ago.

Dr. Rufus: That just seems to be playing with the language.

Willie: In a way it might be, I'm not entirely sure myself.

Tad: What about my objection to our particle being a time traveler?

Willie: Well, there's a lot to be said. Let's make sure we have the argument right. You claim that if there's only the present—as presentists hold—and time travel requires a destination other than the present to which to travel, then there's nowhere for a time traveler to go. Better: there's nowhen for the traveler to go.

Tad: Well put.

Willie: It seems to me that we really have a few relevant options. We can give up our time-travel/backward causation hypothesis—granting that the argument is sound. Or, we could give up presentism; there is still eternalism. Or, possibly we could hang on to both time travel and presentism and try to uncover some flaw in the argument that doesn't demand that we reject presentism.

Tad: The argument looks air tight to me, including the assumption that presentism is true. I lean towards giving up the time-travel hypothesis.

Willie: Well that might be how you see it, but we might at least give it some more thought.

Dr. Rufus: Tempted as I am to just reject presentism, I suspect there is something wrong with Tad's argument. It looks like if Tad's argument works—if it's 'sound', as you philosophers say—then all forms of time travel must be impossible. I kind of doubt presentism has such a strong consequence.

Tad [*with a complacent look*]: Yes. Neither the future nor the past exists if only the present does. And any form of time travel requires the existence of a time other than the present, so if only the present exists, then any form of time travel is impossible.

Dr. Rufus: Einstein's relativity theory tells us that at least a certain kind of forward time travel is possible, and a 1975 experiment verifies this. In this experiment, Carol Alice of the University of Maryland synchronized two atomic clocks—both of which are considered fully-functioning by horologists—and placed one on a plane and flew it around for a few hours and left the other on Earth. When the airborne clock returned to Earth, the time it displayed was a fraction of a second less than that of the other clock. The experiment at least suggests that time can be distorted, such that the closer the body comes to the speed of light, the greater the time distortion. The important point, though, is that it seems like at least some form of time travel is, in fact, possible.

Willie [*to Tad*]: A hypothetical case makes the same point. If a woman were cryogenically suspended for 10 years, and then revived, she'd have experienced forward continuous time travel. She might be convinced it's January 1, 2010, when it's really January 1, 2092. She'd be able to describe nothing about her trip but would have excellent recall of events prior to the suspension. That seems perfectly possible and like a case of time travel. Something must be wrong with your argument.

Tad: That's not time travel!

Willie: Why not?

Tad: I am not sure. Even the atomic clock traveling at high speeds seems a little too mundane to be time travel, but I'll grant you that case. The deep freeze is a different matter.

Dr. Rufus: I agree with Tad about the cryogenic process. In terms of the physics, there is no time dilation; nothing interesting is going on.

Willie: Fine. Whether freezing and thawing is, strictly speaking, a way to time travel is irrelevant. (All I said, by the way, was that it was *like* a case of time travel.) The point I was trying to make is that what's important about traveling is not that the destination be there when the traveler starts out, but that it be there when the traveler arrives. It doesn't matter if January 1, 2092 exists when our woman is frozen, so long as it exists when she's thawed. Similarly, thinking about the 1975 experiment, it doesn't seem important that the arrival time (according to the clock on Earth) exist when the plane starts to accelerate, but it is important that this time exist when the plane returns. The argument seems to overlook this particularly salient detail.

Tad: I don't follow.

Willie: Consider this. It's 1987 and you just graduated from high school. You and some friends have heard of an amazing theme park that is going to be built in central Zimbabwe. You decide to go there for an extended senior trip, figuring that if you start walking when they hand you your diploma, you will get to the park just when it opens.

Tad: Okay, that's a pretty ludicrous story, but I'll play along. Of course, my friends and I will need to do some swimming during our journey.

Willie: True. So, with your first step or as you backstroke across the Atlantic, you are traveling to the theme park, right?

Tad: Yeah, sure.

Willie: Well, the theme park doesn't exist. So you are traveling to a place that doesn't exist. If that is the case, then one of your premises is false, and your argument is unsound.

Rufus begins to smile a bit.

Dr. Rufus: Hang on a second, Willie. I think you've tricked Tad with a little word play. Sure, the theme park in central Zimbabwe doesn't exist yet, but the *location* where it will be exists. So, Tad and his friends aren't really traveling to a place that doesn't exist.

Willie: Okay, I'll concede that my example has that flaw, but think about the expanding universe again. Suppose our universe expanded by creating new spatial locations. You could take a trip to a "place" not currently in the universe, and so somewhere that doesn't exist. However, by the time you got there, it will be in the universe and so will exist.

Tad: I still don't follow. If yesterday doesn't *exist*, then I can't travel there. If tomorrow doesn't *exist*, then I can't travel there. It would be like meeting the Boogiemán or traveling to the Fountain of Youth.

Willie: The difference is that the future will exist and the past did exist. The Boogiemán and the Fountain of Youth never existed and never will exist. You can be traveling to a spatial or a temporal destination that doesn't exist; you just can't arrive at that destination until it exists. When you're traveling to some time or place, you're engaging in traveling behavior; you needn't be arriving anywhere though.

Tad: Yes. But to really be time traveling, wouldn't you have to arrive at some non-present time, which presentists deny?

Willie: I don't think so, Tad. Think about this: Some traveler enters a time machine now and will arrive at some destination in 2010. The presentist should be fine with such a case.

Tad: Something's still screwy. This 'will arrive' business bothers me. It can't be true if presentism holds. Until your traveler arrives at a destination in 2010, it isn't true that she will arrive at that destination. So, how can anyone now be time traveling.

The server clears and offers coffee. His offer is eagerly accepted.

Willie: Sometimes our present-tense statements require for their truth that certain sorts of other situations will (or did) happen. If our waiter is now placing arsenic in your coffee, isn't he now committing a murder even though for that to be true it must also be true that you will drink the coffee and die as a result? To be time traveling (now), you must be engaging in some sort of "traveling" behavior that will cause or did cause a certain sort of "arrival" event.

The coffee arrives. Tad looks his over carefully with a worried expression on his face.

Dr. Rufus: I'd like to cut in for a moment. Willie, it might be helpful if you could show how a popular time-travel story fits with presentism, especially given that these stories often have an eternalist feel to them.

Willie: Well, if one of you will outline one of your favorite time-travel plots, I'll demonstrate to you how the same story can be told in a way that is consistent with the presentist view.

Tad: All right, *Star Trek IV*. Kirk and the Enterprise crew travel back 300 years to Earth, interact with people, find two humpback whales and then take those whales back to the twenty-third century to stop an alien probe from destroying the Earth.

Willie: Very good, I don't remember any obvious contradictions in that one. Now remember, we said that presentists don't deny past- and future-tensed truths. So, suppose its two days after the Enterprise crew picked up the whales (sometime in the 1980's). Also, suppose that presentism is true. Then there *was* a ship that picked up two whales two days ago. In 300 years, that ship *will* appear near Earth, crash, and release two whales. And...

Dr. Rufus: I see the point. All you have to do is express the elements of the story in different tenses to make it fit with presentism. So it looks like a presentist world wouldn't ban time travel after all.

Tad: Hang on a second Professor; I just thought of something else. Maybe the part of my objection about not having anywhere to go is dead, but I still think there is disagreement between presentism and the time-travel hypothesis. Willie, what about the causation our particle must be involved in if it is time traveling?

Willie: Admittedly, there must be some strange causation going on to have a time-traveling particle. No matter which view, presentism or eternalism, is correct, backward causation is remarkable. However, I do propose that the type of causation we're worried about here doesn't raise any special issues for presentism.

Dr. Rufus: Surely if only the present exists you can't have things from different times causing events. The causation must occur in the present.

Willie: You have to remember that causation is not an event. It is a relation between events. It does not take place at a time. Of course, there are countless examples of causal relationships between present and non-present things. For example, the Big Bang caused the Earth to have the orbit it now has. Many of the things we do today will have effects in the future. If presentism is true, then it must explain how nonexistent things can be part of a causal relationship. It must do that regardless of whether time travel is possible.

Tad: I see what you mean. The apparent discrepancy between presentism and causation is not limited to issues of time travel, so it doesn't really help us determine whether time travel and presentism are compatible.

Dr. Rufus: I worry about presentism for scientific reasons. But we needn't get into that now.

Willie: No, go ahead.

Dr. Rufus: What worries me is that presentism seems to presume an absolute frame of reference to distinguish what is real. The present seems to consist of all and only events simultaneous with one particular observer-independent frame of reference. This looks to be quite a departure from special relativity. Special relativity's hallmark is the notion of observer dependence with regard to time. The 1975 case we talked about supported the theory, and there are numerous other examples. If this is right, presentism has to be false.

Willie: Yes, that does seem to be the crux of the matter regarding the truth of presentism, and I am certainly not prepared to defend presentism. Still, I am not sure that this is a distinctive problem either. Lots of our ordinary ways of talking about time, length, and motion look to be at odds with the laws of special relativity. Just as these ordinary ways of talking have to be reinterpreted or altered to accurately describe the world, so maybe does the presentist thesis. Maybe, when a presentist says, 'Only present things exist' his claim would have to be understood as relative to his frame of reference. I don't know.

Dr. Rufus: Once again, this philosophical discussion is all well and good, but it can never do more than tell us whether it is logically possible that the particle is time traveling. It's up to science to show whether it is real or not. So, let's table the discussions for a while, until we have some data to back up our ideas. With any luck, and some computer wizardry from Willie, we'll make some progress tomorrow.

FRIDAY

At 7:00 in the morning, Rufus and Willie are sitting at the computer console with cups of coffee, intently discussing something. Tad enters the room and joins them.

Tad: Wow! I thought *I* was getting an early start!

Rufus [*looks up*]: Oh, Tad. I didn't hear you come in. Come join our stimulating conversation.

Tad [*heading towards coffee pot and yawning*]: I think I need to have some stimulating caffeine before I have any stimulating conversation. [*Sees empty coffee pot*] Hey! Don't you know that the first one in is supposed to make the coffee?

Willie [*dryly*]: I did.

Tad looks again at empty coffee pot and then back over at Willie. Willie holds up his mug for Tad to see and tips it upside down to make his point.

Tad: Uh oh. What does that much caffeine do to a philosopher?

Willie: Hey, if the Department of Energy wants this work done, they'll have to loan me some of *their* energy. You can make the next pot. I think I saw some decaf in the cabinet.

Tad [*mock horror*]: Decaf?! [*Shakes head sadly, wondering if he and Professor Rufus could survive the day on decaf as he starts a fresh pot*] So is that the program that turns off the glitch if two particles appear in the chamber?

Dr. Rufus: No, it isn't. Willie has been trying to sell me on some new ideas for variations on the experiment.

Willie: I wrote the program that deactivates the glitch if two particles are present yesterday, while the two of you were at your conference. The program that is running right now is in a way the opposite of that program. Instead of turning the glitch *off* when the second psi-lepton appears, this new program does not turn *on* the glitch *until* the second particle appears.

Tad: Wait a minute. Let me make sure I have this straight. The glitch is off initially, but if two particles appear in the chamber, the program will turn on the glitch.

Dr. Rufus: Yes.

Tad: Why are we bothering to run this program at all? I think it's pretty obvious what will happen. Whether or not your time-travel hypothesis is correct, if the glitch is turned off, then the chances of the second particle spontaneously appearing are virtually zero. It will look exactly like the trial without the glitch that we ran on Monday; the psi-lepton will just decay normally.

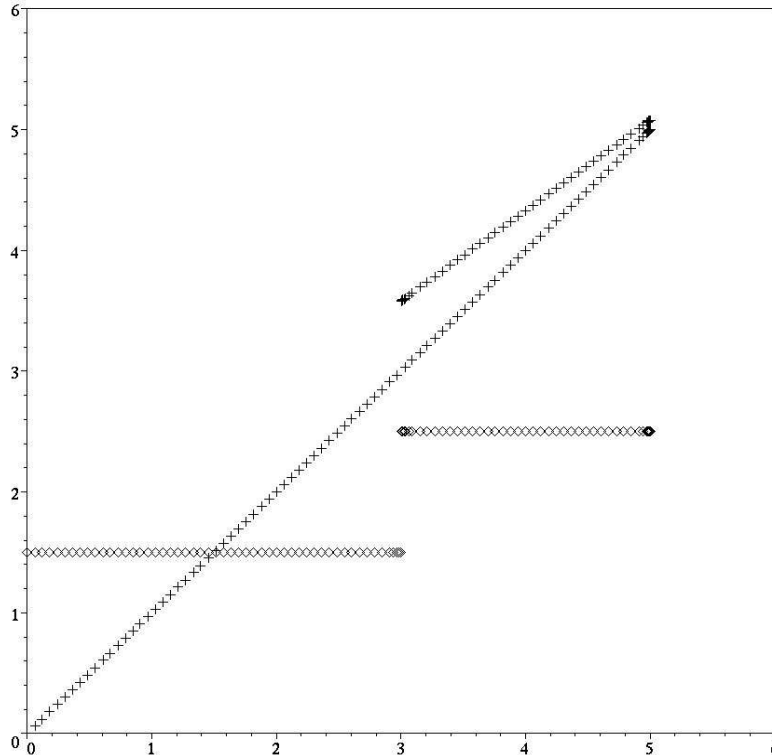
Dr. Rufus: Maybe, maybe not. We thought we knew what our data would look like the first time we isolated the psi-lepton, but we were certainly wrong then! In order to approach this problem scientifically, we need hard data, not speculation. Our knowledge of the psi-lepton's behavior is based almost entirely upon theory, and this glitch throws another unpredictable factor into the equation. I really don't think we can assume anything at this point.

Willie: Besides, I don't think the outcome is as obvious as you believe it is, Tad.

Tad: What else could happen?

Willie [*punching a few keys*]: Well, let's find out!

Tad starts the particle accelerator. All three gather around the computer screen.



Rufus [*slightly amused*]: Well, Tad, *that's* why we should never assume that we know what the outcome of an experiment will be.

Tad: [*Walks over to the printer, picks up graph and scrutinizes it*] How is this possible? This data looks just like all of the other trials in which the glitch was turned on.

Dr. Rufus: So the second particle turned on the glitch that caused the second particle that caused the glitch and so on.

Tad: That shouldn't have happened even if the time-travel hypothesis is true. When the program was started, there was no glitch. No glitch means no second particle. Therefore, unless this just happened to be the one-in-800-bazillion times that a psi-lepton spontaneously appeared in the chamber, the experiment should have gone just like Trial 46.

Willie: Yes, that is one outcome that would have been consistent with our hypothesis. However, I believe that the actual results are consistent as well.

Tad: How can you say that? The second particle is clearly present in these results. According to your theory, the second particle should not appear unless the glitch causes it. However, the glitch was turned off in this program, so there was nothing to cause the second particle.

Willie: Not necessarily. Consider this. The second anomalous particle appeared, causing my program to activate the glitch. The glitch then caused the psi-lepton to change its temporal orientation, thus appearing at the earlier time. The graph would look like the graph that you just printed out.

Tad: But there was nothing to cause the second particle.

Willie: Yes, there was. The glitch caused it.

Tad: But the glitch was turned off.

Willie: The glitch was *initially* turned off, but the second particle turned it on.

Tad: But the second particle shouldn't have been there!

Willie: Well, it was. Look at that graph that you're holding.

Tad: But there was nothing to *cause* the second particle.

Willie: The glitch caused it.

Tad: But-

Dr. Rufus: Guys, you're going around in circles.

Willie: Exactly. We're talking about a causal loop here. Each event is among its *own* causes.

Tad: But what caused the loop itself? There is no reason that we should have this particle-glitch causal loop rather than no loop at all.

Willie: Is that really true? You could say that starting up the accelerator caused the loop; if you hadn't started the machine, then this causal loop wouldn't have occurred.

Tad [*pauses*]: Well, I suppose you're right, but that wasn't really what I was getting at. Once the experiment started, there must have been something...some conditions that led to the occurrence of the loop rather than to the ordinary decay of a single particle.

Willie: Well, you know, not all events are completely determined by initial conditions and the laws of nature alone. Quantum mechanics, for example, is inherently indeterministic. Even if you know the state of the universe and the laws of nature, you cannot predict future events with absolute certainty. All you can say is that there is a certain probability that each outcome of an event will occur.

Tad: Maybe we can only express these outcomes in terms of probability because we're missing some information that would tell us for sure which outcome would occur.

Willie [*shaking his head*]: Maybe. However, according to the standard interpretation of quantum mechanics, the reason we have to use probability isn't because we *don't* have enough information; it's because events do not follow necessarily from initial conditions and natural laws. The universe is genuinely chancy. Even if you knew *everything* about the universe, you *still* could not say what would happen in the future with absolute certainty. You seem to be advocating determinism, Tad. Determinism states that the laws of nature and the state of the universe at any one time completely necessitate the state of the universe at all future times.

Dr. Rufus: So if determinism is true, then it is possible to predict the outcome to any event with absolute certainty. With determinism, if we have to use probabilities, it is only because we are missing some relevant information, as Tad was saying a minute ago.

Willie: Exactly. However, even if the universe is deterministic, it does not follow that everything has a cause.

Tad: It doesn't?

Willie: It appears that way at first glance. However, you could have a universe in which determinism was true but not every event had a cause. For instance, the origin of the universe could be some "uncaused cause," but from every point then on, determinism could hold true.

Dr. Rufus: Besides that, determinism doesn't seem to explain what *caused* the laws of nature to be the way they are.

Tad: I'm still not sure that I'm convinced. It seems to me that all of the relevant initial conditions were the same as they were in the other trials without the glitch. The laws of nature certainly didn't change, so why was this trial different than Trial 46?

Willie: How can you say that the initial conditions were the same? The computer was running a different program.

Tad: The glitch was turned off initially, so I don't see how that makes any difference.

Willie: Still, you can't deny that the initial conditions were not *exactly* the same. Besides, if we're considering backwards causation, different *later* conditions might be more important than different *initial* conditions.

Tad: Well, *I* still don't think it should be any different. On the other hand, if indeterminism is true, and we think about this in terms of probability, then the chance of a second psi-lepton spontaneously appearing is on the order of 10^{-800} , or essentially zero.

Willie: I think that part of the problem is that we're used to thinking about causes and effects in a linear fashion. Normally, causes are independent variables, and effects are dependent variables. If we manipulate the frequency of our cause, we can manipulate the frequency of our effect. For example, if my throwing a baseball at a window causes the window to break, I can break more windows if I throw more baseballs at windows.

Dr. Rufus: But in our causal loop, every event is both a cause and an effect.

Willie: Exactly. I don't think any event in our loop really fits our definition of a 'cause' or an 'effect.' Therefore, I don't think we should try to identify the 'cause' of our loop in the terms of the ordinary, linear relationships that we are used to dealing with.

Tad: Well, I'm sorry, but if I am too linear, then you are downright loopy!

Dr. Rufus: Right now, I think we ought to try our other program. I believe this trial will really be the one to give clear evidence for or against our time-travel hypothesis. We have all the time in the world for data analysis and philosophical speculation.

Tad: [*sarcastically*] Yes, especially if we can time travel!

Willie: I'm uploading the program now.

Tad: I still don't think causal loops make sense. They make all sorts of ridiculous situations possible.

Willie: Such as?

Tad: Well, I once saw this movie called...um...*Somewhere in Time*, I think.

Dr. Rufus: You think?

Tad: Well, I wasn't very interested in it. It was kind of romantic and stuff, and well, it wasn't *Terminator*. Anyway, I *do* remember that there was a young man, a playwright, I think, who was visited by an old lady in the 1970's, and the woman gave him a watch and then left, saying only,

“Come back to me.” Several years later, he saw an old picture in a hotel of a beautiful young actress that fascinated him. He did some research and found a picture of that actress as an older lady, and he realized that it was the same woman who had given him the watch. Unfortunately, she had died on the same night that she visited him. After talking to a professor who had written a book about how to time travel by hypnotizing yourself, he went back in time to 1920. Once there, he found the young actress, and they fell in love. Before returning to the 1970's, he gave her the watch that she, as the old woman, had given him. As a result, the history of this watch formed a complete loop.

Willie: What’s wrong with that? It sounds to me like the watch had a complete, consistent causal history. The man gave it to the actress in 1920. She carried it with her until 1970 and then gave it to him. He then returned to 1920 and gave it to the actress.

Tad: What do you mean, what’s wrong with that? Nobody ever *made* the watch!

Willie: So?

Tad: So that’s impossible! Watches don’t just appear out of thin air!

Willie: Actually, in theory, objects like that watch, called *jinn*, are possible, though highly unlikely. Correct me if I’m wrong, Professor, but quantum mechanics says that it is possible for macroscopic objects to spontaneously appear.

Dr. Rufus: Yes, it’s *possible*, if you have enough energy. As you said, it’s just *extremely* improbable.

Willie: So *jinn* are possible. However, the larger they are, the less likely they are to exist. Something as big as that watch would probably just be really, really, *really* unlikely, instead of only *really* unlikely!

Tad: There is still another problem with these *jinn*. In order for the story to be consistent, the watch would have to be exactly the same when the actress “first” received the watch and when the man took the watch back in time and gave it to her “again,” right?

Willie: Absolutely.

Tad: If that’s true, then the watch wouldn’t be able to age at all. The actress carried around for fifty years or so. Even if you assume the watch didn’t rust or get dropped or scratched or something that would change its actual appearance, its entropy is still going increase over that time.

Willie: Well, I’ve done a little bit of reading about *jinn*, and philosophers do acknowledge that the outside world must expend energy to return a *jinni* to its original state. I don’t really understand it myself, but I can recommend some books if you’re interested. Ah, the program is ready to go!

Tad: I still maintain there’s not really any need to run this program.

Willie [*amused*]: What? Are you scared that you'll be proven wrong if we run this trial?

Tad: No. There is no doubt in my mind that I will be proven right. I'm just trying to save some money for the Department of Energy. If we can turn off the glitch after the appearance of the second particle that was caused by the glitch, which we surely can, then we would obviously end up with a contradiction. That means that backwards causation is impossible, just as I have said all along.

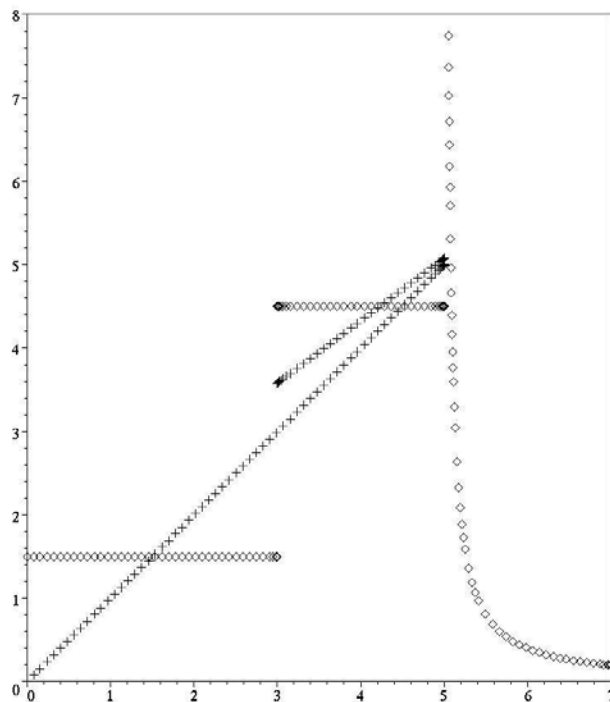
Rufus [*laughing*]: Are you as confident about your predictions about this trial as you were about the last trial?

Willie: Hey, we might all be surprised by the results. Tad, are you ready?

Tad: Here it goes!

Everyone watches the computer screen intently.

Willie [*startled*]: Whatever that was, it *definitely* wasn't expected!



Rufus [*retrieves and studies printout*]: This spike is from the energy residuals that we spoke of earlier, the ones whose absence was puzzling us. The second particle appeared, just as it did in all of the other trials with the glitch, but this time, it appears that the two particles simply annihilated each other.

Tad: Well, I'm glad that we ran this trial and saw the residuals, but, as I expected, it looks as though the time-travel hypothesis is shot. If the "second particle" was really the first one traveling backward in time, then it wouldn't have been able to collide with the "first particle." We're back to the drawing board.

Dr. Rufus: Well, that's assuming that the program ran as intended. Willie?

Willie [*typing*]: I can't imagine that it didn't work. Based on the previous trial, the computer is obviously able to turn the glitch on or off in the interval of only a couple of nanoseconds. [*Pauses for a second*] Yes, the self-diagnostic log shows that the glitch was turned off.

Silence for a few minutes.

Willie: I guess one possibility that we never really thought about was that both the second particle and the glitch could have been caused by some third event. Just because flowers bloom and geese fly north in the spring doesn't mean that one of those events caused the other; they are correlated because they are both caused by warmer weather.

Tad: But that still doesn't explain why there were never any energy residuals until now.

Willie: What if some third factor was causing the second particle, and the glitch was causing the particles not to annihilate each other?

Dr. Rufus: Well, if the glitch wasn't causing the second particle, why didn't the second particle appear in Trial 46, when the glitch was never in place? For that matter, why did both particles simply disappear?

Willie [*shaking his head*]: I can't think straight about this. It's practically impossible to draw any conclusions without knowing exactly what that glitch is.

Dr. Rufus: I don't want you digging around in my hard drive yet! Before we risk altering our experimental setup, we need to run more repetitions of the programs that we already have and to develop more variations on our experiment. I firmly believe that with more data, this mystery will become clearer, and perhaps we will get some new ideas or some supportive evidence for our original idea.

Tad: You mean the time-travel hypothesis?

Dr. Rufus: Absolutely. The psi-lepton obviously was not time traveling in this last trial, but that does not necessarily mean that it wasn't doing so in the other trials with the glitch!

Willie: I hadn't thought about that. I suppose the conditions in this most recent trial were different enough from the original program with the glitch that that could be the case.

Dr. Rufus: After we have gathered as much information as possible about how our psi-lepton responds to different programs and if it behaves consistently in multiple repetitions of the same program, *then* we'll investigate the glitch itself. So, Willie, I hope you've enjoyed writing these new programs, because if you don't mind hanging around here, then you'll be creating a lot more of them. I've already thought of several more variations on the program that we could try.

Willie: I wouldn't miss it for the world!

Dr. Rufus: Tad, I'd like for you to work on a way to "tag" our original psi-lepton particle. If we can do that, maybe we can establish with more certainty whether or not our second particle is the same particle as the first one.

Tad [*nodding*]: That's a good idea. We should have thought about that earlier.

Dr. Rufus: For right now, let's run our programs several more times, and we'll see if we get the same results.

Willie [*grinning*]: Sounds like today's going to be a long day, Tad!

Tad [*laughing as he starts the accelerator*]: Knowing the Professor, I can promise you that we're only getting started!

Willie: I'll put on a fresh pot of coffee.

NOTES

Monday identifies issues raised in popular time-travel movies, touching briefly on the infamous grandfather paradox. The movies mentioned are:

Back to the Future. Dir. Robert Zemeckis. Universal, 1985.

The Terminator. Dir. James Cameron. Orion, 1984

Terminator 2: Judgement Day. Dir. James Cameron. Tristar, 1991.

Tuesday explores issues about identity-over-time and how they connect to the possibility of continuous time travel. The importance of an object's causal history to its identity is discussed in Sydney Shoemaker's (1984) *Identity, Cause, and Mind*, Cambridge: Cambridge University Press and Chris Swoyer's (1984) "Causation and Identity" *Midwest Studies in Philosophy* 9, 593-622.

Wednesday raises issues dealing with the puzzling nature of backwards causation. It begins looking at how backwards causation can ever exist and addresses free-will concerns. Some similar issues are addressed in David Lewis (1976) "The Paradoxes of Time Travel" *American Philosophical Quarterly* 13, 145-152; Michael Dummett (1964) "Bringing About the Past" *Philosophical Review* 10, 338-359; and Gilbert Ryle (1954) *Dilemmas* (Cambridge: Cambridge University Press), pp. 15-35. All three of these papers appear in (1987) *Puzzles, Paradoxes, and Problems* (New York: St. Martin's Press). This chapter also explores issues concerning backwards causation by analyzing the bilking argument within the context of Professor Rufus's experiment. This has been cited many times in philosophical writings. Examples include: Evan Fales (1990) *Causation and Universals* (London: Routledge), p. 134; Paul Horwich (1995) "Closed Causal Chains" in *Time's Arrow Today*, S. Savitt (ed.) (Cambridge: Cambridge University Press), p. 259-267; and Anthony Flew (1954) "Can an Effect Precede its Cause?" *Proceedings of the Aristotelian Society* 28, 45-62. Movie discussed:

12 Monkeys. Dir. Terry Gilliam. Universal Pictures, 1995.

Thursday focuses on presentism as the source of an objection to the possibility of time travel. The argument Tad gives is adapted from Simon Keller and Michael Nelson (2000) "Presentists Should Believe in Time-Travel" *Australian Journal of Philosophy* 79, 333-345. Willie's relativization-of-tense reworking of time-travel plots is also examined in this paper. The two-clocks experiment mentioned by Professor Rufus is a genuine experiment and is described, among other places, on http://www.timetravelinstitute.com/article_tti.php?2734. Some of Professor Rufus's remarks are derived from Ted Sider's (2002) *Four Dimensionalism: An Ontology of Persistence and Time* (New York: Oxford University Press, Inc. 11-52.). Movie discussed:

Star Trek IV: The Voyage Home. Dir. Leonard Nimoy. Paramount, 1986.

Friday delves into puzzling questions surrounding causal loops and their explanations. Chapter 12 of D. H. Mellor's book *Real Time II* offers a highly technical argument against the possibility of these causal loops. Phil Dowe responds to this argument in "Causal Loops and the Independence of Causal Facts," published in 2001 and found in *Proceedings of the Philosophy of Science Association* 68, pages S89-S97. The example of a *jinni* was drawn from the movie:

Somewhere in Time. Dir. Jeannot Szwarc. Universal Studios, 1980.

A discussion of these mysterious objects, which was used in writing this dialogue, can be found in Gott (2001) *Time-Travel in Einstein's Universe* (Boston: Houghton Mifflin), p. 20-24.