Deutsch vs. Lloyd, Brain Tennis, Hotwired, July 1997

Dear David,

I am writing to relate to you a strange thing that happened to me a few weeks ago in the MIT bookstore. I was standing in front of a bookshelf, trying to decide whether to buy your new book or Roger Penrose's. Now as you know, neurons are notoriously sensitive cells, capable of amplifying very small effects. As a result of a tiny quantum-mechanical fluctuation, a few extra transmitter chemicals jumped across one of my synapses and bound to the receptors on a neuron. This extra stimulation pushed the neuron over its threshold and caused it to fire, triggering a burst of neural activity and causing me, on impulse, to buy your book, The Fabric of Reality. Upon reading this book, I discovered that you espouse the so-called "many worlds" interpretation of quantum mechanics, in which every quantum fluctuation causes the world to split into different parts, each one of which is equally real. You seem to be implying that in another equally real world there is another me, equally real, who is currently reading Penrose's book. How dare you imply this! I really bought your book, I really like it, and I really prefer to be reading it rather than Penrose's book. Who are you to say that imposter in the other world is just as real as me? I await your response.

Yours sincerely,

Seth Lloyd

Dear Seth,

I'm glad you enjoyed The Fabric of Reality, but are you sure that you chose it randomly? Most readers, I'm sure, buy it as a result of rational thought, in which case most of their counterparts in parallel universes buy it too. But to the extent that your decision did depend on random events, there are indeed other, equally real, versions of you in other universes, who chose differently and are now enduring the consequences.

Why do I believe this? Mainly because I believe quantum mechanics. Just write down the equation describing the motion of those fateful transmitter molecules, and their effect on you and on the environment. Notice that their "randomness" consists in their doing two things at once: crossing that synapse and not crossing it; and that the effect on you

was likewise that you did two things at once: buy my book and buy Penrose's. Such effects spread out, making everything do many things at once, which is what we mean by saying that there are "parallel universes."

Furthermore, the universes affect each other. Though the effects are minute, they are detectable in carefully designed experiments. There are projects underway - close to your heart, I know, as well as mine - to harness these effects to perform useful computations. When a quantum computer solves a problem by dividing it into more sub-problems than there are atoms in the universe, and then solving each sub-problem, it will prove to us that those sub-problems were solved somewhere - but not in our universe, for there isn't enough room here. What more do you need to persuade you that other universes exist?

Yours sincerely,

David

Dear David,

Thank you for your response: I feel sorry for the other me in the parallel universe who accidentally bought Penrose's book and is debating him instead. But since I'm really debating you and not Penrose, I don't understand why you refer to my shadowy twin in the parallel universe as equally real. Call me old-fashioned, but I like to refer to things in this universe as real: I really had toast, not cereal, for breakfast; I really drank tea, not coffee; and I really am writing this letter to David, not Roger. The toast, the tea, and this letter are real in a way that my Penrose-reading twin is not: The toast can satisfy my hunger, the tea my thirst, and our correspondence my curiosity, but nothing that my parallel twin can do can make any difference to me, to you, or to anyone in this universe that we really do inhabit.

The reason that my twin can make no difference lies in the physical phenomenon of decoherence. As you know, decoherence is a process that robs quantum states of their ability to interfere with one another. The hotter and more intrusive the environment of a quantum system, the more rapidly decoherence takes place. I'm a mammal, you're a mammal. The mammalian brain is a hot, wet place. Within a tiny fraction of a second after the quantum fluctuation had taken place that set in motion the chain of events that caused me to buy your book rather than Penrose's, the universe in which the neuron fired and my hand reached to D had separated irrevocably from the universe in which the neuron didn't fire and my hand reached to P. (The tendency of the brain to decohere its contents is the reason Penrose's claims for the importance of quantum coherence for consciousness

should be regarded with skepticism.) Once decoherence has taken place, my twin can no longer interfere with me, and has ceased to be real in the way that you, who can argue with me, are.

Quantum computers, in contrast to our brains, operate coherently. I am comfortable with the notion of a quantum system such as a photon being many places at once - my eye wouldn't function unless each photon passed through all points in the lens simultaneously. Why then can't a quantum computer effectively perform many computations simultaneously without the universe splitting into many parts?

Yours sincerely,

Seth

Dear Seth,

So you admit that photons, atoms, and quantum computations have invisible, differently behaving counterparts, but you still cling to the belief that you exist in only one copy. I don't think this makes sense, because you are made of atoms, and if they have invisible counterparts, so must you.

Look inside a quantum computer during a computation. The particular set of values you see in its registers corresponds to one particular computation - but you agree that, in fact, it was performing vast numbers of other computations at the same time, computations of which you detected no trace. Now, in the example you gave, quantum mechanics describes you as performing two different computations (viz., reading two different books). Yet you maintain that when you check your own memory and remember reading The Fabric of Reality, then that is the only reading that has been going on. Your excuse for treating these two cases differently, when their quantum-mechanical descriptions are perfectly analogous, is that the quantum computer gives you an output which depends logically on vast numbers of invisible computations, so you must accept that they really happened. By contrast, the other computations that quantum mechanics says that you performed (such as reading Penrose's book) can never affect you because of decoherence, so you prefer to believe that they never happened. But decoherence is just a matter of degree. There is never a moment after which an object's invisible counterparts cannot affect it any longer. It just gets too expensive to set up the apparatus that would demonstrate their existence. To claim that if something is too expensive to measure, it doesn't exist, is surely just a perverse form of solipsism.

Shoot a photon out into an empty region of the night sky. Unlike decoherence, this

is a truly irrevocable act: If you change your mind, the laws of physics say you'll never retrieve the photon. Yet you wouldn't deny that it still exists, would you? The proper criterion for whether something exists is not whether it can still affect us, but whether it figures in our best explanation of what affects us. To deny the existence of that photon, or of those invisible computations, or invisible universes, is to renounce explanation of what we do see.

Yours sincerely,

David

Dear David,

You champion the existence of multiple me*s* and assert their equal claim to reality; I insist on my prior claim, since I am really debating you while the other me*s* are not. Rather than imitating my daughter and repeating "me me me" until you give up, let me try to first find where we agree and then where we differ. I think that we agree that that quantum description of the universe (the "wave function") is constantly branching into different "worlds," in one of which we are debating now, in another of which I am debating Penrose, and in others (I hope the plurality) of which we are amicably sipping margaritas on the beach. Each one of these "worlds" seems equally real to its inhabitants, even if these multiple realities are mutually exclusive. In addition, quantum mechanics picks out no one of these "worlds" or branches as special.

So far, so good. Now, as I understand your position, you assign all of these "worlds" an equal measure of reality and claim they all exist. Here we differ. Arguing with philosophers has made me wary of putting too great a burden of meaning on the words "exist" and "real." But the conventional use of those words refers to objects and events in our particular branch of the universe. The cup of tea that I am drinking exists; we are really debating. In contrast, the other branches or "worlds" are exactly the parts of the wave function in which the cup of tea does not exist and we are not really debating. These other "worlds" do not exist in the way that this one does. For better or worse, I suspect that most people will believe that the branch of the universe in which pigs fly exists only when pigs actually fly.

We differ on more than semantics, however. From your clear and elegant discussion of quantum computation, I can tell that we differ also as to the point at which the universe branches into different "worlds." You argue that one must accept the existence of the other branches because these branches could interfere with our branch in the future. For

decoherence, however, the issue is not whether the branches could interfere with each other, but rather whether they actually do interfere with each other at some time in the future. Decoherent branches, by definition, do not interfere with each other: As a result, when the universe splits into two decohering branches, the split is irrevocable, and for all intents and purposes the other branches and their corresponding "worlds" do not exist.

In a quantum computation, as you point out, the branches actually do interfere with each other, allowing the computation of quantities, such as factors of large numbers, that are properties of all the branches taken together but not of any branch in particular. (This performance of the computation in many branches is at bottom no stranger than the single photon that, at your suggestion, I shot into the air last night occupying many points of space at once.) But the very fact that the quantum computer gives us an answer that depends on all the branches at once means that the universe has not really split: Those branches were part of our world, not of other worlds! The universe splits if and only if its branches decohere.

Thanks for a great debate, better than the one I had with Borges on the same subject. I met him at a garden party in Cambridge in the last year of his life, and asked whether he had quantum mechanics in mind when he wrote his wonderful evocation of a branching universe, "The Garden of Forking Paths." His answer: "No."

Yours,

Seth

Dear Seth,

Our disagreement is certainly about more than just semantics; however, your latest reply suggests that our positions may be closer than your forthright opening remarks might have indicated.

Our key area of agreement is, as you say, that what quantum mechanics describes is not a single universe but something that "is constantly branching into different 'worlds,' in one of which we are debating now, in another of which I am debating Penrose."

You also say: "The very fact that the quantum computer gives us an answer that depends on all the branches at once means that the universe has not really split: Those branches were part of our world, not of other worlds! The universe splits if and only if its branches decohere." I entirely agree! Reality consists of a multiverse, an enormous entity which, on a gross scale, has a structure that resembles many copies of the universe of classical physics, but which is, on a sufficiently fine scale, a single, unified system. In an

absolute sense, there are never any splits at all.

Our key point of disagreement is that, despite the fact that "quantum mechanics picks out no one of these 'worlds' or branches as special," you still want to believe that "these other 'worlds' do not exist in the way that this one does."

If you are right, it surely follows that the thing that singles out our own branch as more real than all the others is nowhere to be found in quantum mechanics. Nor is it, of course, anywhere to be found in our experience, since, as you say, "each one of these 'worlds' seems equally real to its inhabitants." So where is it to be found? It is found in (or rather, demanded by) philosophy - and in particular, I believe, by the sterile philosophy of positivism and related doctrines that have been impeding scientific progress for the last seventy-odd years. You say: "Arguing with philosophers has made me wary of putting too great a burden of meaning on the words 'exist' and 'real.'" There may lie your problem: I think you have been arguing with the wrong philosophers!

Yours sincerely,

David