TIME TO TUNNEL

"There's no use trying … one can't believe impossible things," [said Alice.]

"I daresay you haven't had much practice," said the Queen. "When I was younger, I always did it for half an hour a day."

Lewis Carroll (1865)

In classical mechanics a particle with energy lower than the height of a potential barrier is forbidden to overpass it. In quantum mechanics, it turns out that under this circumstance the particle can tunnel through the barrier, instead.

Wu Zhong Chao (1995)

In the tunneling picture, it is assumed that the universe originated at small size and then expanded to its present, large size.

Alexander Vilenkin (1995)

Quantum tunneling processes, which are familiar to physicists and routinely observed, correspond to transitions which do not have a classical path.

John Barrow (2007)

The Red Queen has it right. Believing things that are impossible takes lots of practice. Maybe it's easy if you're young; he's not. Like other problems round here this one is now mine: I have to walk him through lots of impossible and he won't go there. Not that he doesn't want to; he can't get his head around it. But at least he's here this morning and, momentarily, so's she.

On her way out she asks what we're up to, so I tell her, tunneling. Her reaction is revealing. She is like: Okay. I mean, what would that word mean to the average person? But it seems it's nothing new to her. The thing is: Why would she conceal the fact—it's fact as far as I'm concerned—that she's a physicist? I file it in my growing what's-wrong-with-this-picture folder. Not on my computer; in back of my head.

The solution to my problem is he's into snooker. There's no table but a thought experiment will do. So I get him to imagine a table with a ramp-like barrier, a strip across it with a section like a flat inverted V. Let's say, I say, two feet across, an inch high in the center. Flat to the table either side. Although he's never seen it, he can think of looking at it, cue in hand. Now, I tell him, hit the cue ball softly at the barrier. Watch it roll up the ramp part way and then roll back. Now hit it harder and then next time harder. If it has enough energy to reach the top it rolls on over. If not, it rolls back. Always. This, I say as if the table's really there, is classical behavior.

Things are otherwise in Quantumland. Hit softly, QM cue balls too do not roll over, but they sometimes show up on the other side! Or, hit hard enough to reach the top, they may roll back. There is no certainty with QM cue balls on a QM table. Hit hard or soft they always play the odds. No matter how it's hit a QM cue ball may not make it to the far end. And, hit oh so softly, there's a chance it may arrive.

Makes no sense? One look at him confirms it. Welcome once again, I say, to Quantumland.

QM is just what the Red Queen ordered. It's riddled with impossibilities. Tunneling might top her list. But it only seems impossible. It's real. It happens. Atoms tunnel all the time. To make the point I say: Look at my hand. Hesitant, his eyeball hooks it. It is, I say, a tunnel factory. The molecules that make it move must tunnel every second many million times.

To tunnel is to teleport. Things go from A to C; they don't pass B. It works even though they *cannot* be at B; they don't have the energy to get there. They just cease to be at A and take up residence at C. Or maybe not. Any moment they can do it. But more often they do not.

How do they move from A to C? An early clue arrives in '32. MacColl, at Bell Labs, uses then-new QM theory to calculate how long an electron takes to tunnel through a barrier. He finds that it happens with 'no appreciable delay.' In '95, Wu Zhong refines this calculation. He shows the trip 'under' the barrier takes no real time at all. Which is to say: The time taken is imaginary. I imagine that the Red Queen would be pleased. Some have different opinions. They say the transit takes real time. But QM says that transit time has no clear definition so debate may not stop soon.

So, the time 'in transit' *may* be zero; so I tell him; so they say. Luckily he has no need to know exactly what this means. But it seems to me that it should interest him. Why? Well, if things tunnel now, why not in the Beginning? And it seems in the Beginning there was not a lot of time. I eye him time to time; he doesn't buy it. His problem is he's not a fictional detective. A flic who's fictional would not just buy it, he would fantasize. He'd be tunneling all over town. Like 8Ball and MJG he'd do it big time. Coming up the Grapevine on I-5 he'd be out of gas. No way to climb the Tehachapi Mountains. He'd just blink and find the mountains are behind him. Still on I-5 looking south, still out of gas, but now he's looking down at San Fernando. He does it *without going through* the Tejon Pass! In fiction as in QM the impossible can happen any time.

QM shows the chance that this will happen in the lifetime of the universe is next to zero. But not zero. The chance is small because a car is big and the Tejon Pass is high and wide. But for sub-atomic particles and molecule-thin barriers, QM says the odds are good. Measurements confirm it. They show it goes on all around us all the time. It's a fundamental part of how things work. Nothing in the world would be the same without it. It may be weird but it is where we live. And it's quick like quantum rapid transit. Does its speed exceed the cosmic limit? Well, it may look that way but, actually, no. The trick is that it's rapid but there is no transit. Here's how: QM says that, left to its own devices, matter is a maybe. It's a fuzzy mixture of all outcomes anyplace. Until someone makes it be someplace by checking where it is. How can I get this through to him?

This time I ask him for a finger. Not the middle. He raises his left pinkie; he's still bored. He seems not to be embarrassed that he's chewed the nail. It's made, I say, of protein molecules. Electrons tunnel their way through them all the time. Sharing the electrons is, I tell him, why his fingernails don't fray. It's a cheap shot; but he doesn't get it. Now, I say, think of one electron. It's in an atom that's in a molecule that's in the nail. Tunneling, how far can this electron hope to go?

Its Wave Function holds the answer. We need to multiply its value by itself. The answer says that—if we don't look for it—this electron's partly far away. For example, 55-Cancri is a star some 40 light years from our sun. It has planets; at least five. The value of his nail's electron's Wave Function at, say, planet one's north pole is very small. Decimal a page of zeros something. But QM says the something isn't zero. 55-Cancri's barely out there in our galaxy, let alone the universe. Smeared meaninglessly thin, his nail's electron extends through all the reaches of the cosmos. The total probability's exactly one.

He looks like he's glazing over. What can I do? He needs a wake-up but that's not my job.

Anyway, as Susskind bluntly says: Who cares? Well, he is writing about black holes and how bits of *them* can tunnel so *I* care. So should Frank. And when it comes to the smeared-out Wave Function another answer is: Quantum mechanists. *They* care. Smearing gives them lots of trouble. QM says it reaches everywhere in zero time. It's called instant action. It's not just tunnel trouble. The Wave Function gives the chance a particle is anyplace if someone checks. When they check, it's someplace in an instant. The someplace may be unexpected. It's like it *was* there all along. Back to his finger and its fraying nail. Until he checks it, his nail's electron's smeared out everywhere. The instant that he checks, it snaps together someplace like old roadkill in reverse. Is it possible to move a universe this way?