THE MEASUREMENT PROBLEM

'But I don't want to go among mad people,' said Alice.

'Oh, you can't help that,' said the Cat.

'We're all mad here. I'm mad. You're mad.'

'How do you know I'm mad?' said Alice.

'You must be,' said the Cat, 'or you wouldn't have come here.'

Lewis Carroll (1865)

It's the theory that determines what one can observe.

Albert Einstein (1926)

One would get into hopeless difficulties if one tried to describe what happens between two consecutive observations.

Werner Heisenberg (1958)

It would seem that [QM] is exclusively concerned with 'results of measurement' and has nothing to say about anything else.

John Bell (1981)

Is the Moon there when nobody looks?

David Mermin (1985)

Kerner. Every time we don't look we get wave pattern. Every time we look to see how we get wave pattern we get particle pattern. The act of observing determines the reality.

Blair. How?

Kerner. Nobody knows.

Tom Stoppard (1988)

The real world out there … must exist independently of us.

Lee Smolin (2006)

My day begins with Carroll's Cat. It seems a good beginning. Carroll's fun. The phone's ring bursts my bubble of contentment.

Adolf? says the earpiece to my answer. Then—as mine is not the voice that he expects—Adolf Harvedin? That's the sound I register but my temporal lobe sets out to turn it into Hardin. And maybe Adam? No Hardin here, I say, and he hangs up.

Wrong number, I think. Then, as if this is disputed, I tell myself that's all it was, a wrong number on a phone that rarely rings. I suppress a feeling it was not

the number that was wrong. Minutes later, poking absently at Carroll pages, I give up and go to Google. Could it have been Hardin? I try the funny name I think I heard.

Just one hit. It brings up blocks of text and lots of people-pictures. Control-F Harvedin gets me a caption under one of two group photos. Adolf Harvedin, it says, is in the back row, second from the left. But it is Frank! It's him. It's he. The office wavers. My spine tingles all the way into my hair. A sudden fear that he'll arrive and see it makes me kill the tab. Later I can check it safely. Meantime, what is going on? Who's the caller? The page on Alice and the Cat is back but now it is pure smokescreen.

As happens when I am confronted with a quandary, my thinking wanders. Could Carroll's Cat have come from Copenhagen? Frank or Adolf or whatever has already seen a cat in a predicament about a quantum measurement. Though the problem's famous it's completely mad. Some inner voice is telling me this madness masks a message from QM. I dig out my QM notes again.

A QM calculation starts with a complete description of the quantum state of any quantum system. A quantum system's anything, some atoms for example, that physicists can describe with a quantum state. In principle it's anything at all; in practice it is easier with some things than with others. A proton and an electron—an atom of hydrogen—is a quantum system. It has a Wave Function, which gives its quantum state. For example, an excited state with the electron zinging round the proton in a higher orbit than its lowest energy or ground state. The evolution of the Wave Function gives a description of the future of the quantum system—how it changes over time. The electron could remain excited. Or not. If not, it could give up energy, which flies off as a photon. The Wave Function covers all possibilities.

The future that QM foretells depends on the initial state and nothing else. It foretells the future just as long as no one checks to see what's going on. It gives the odds each possibility will turn up when a measurement is made. When someone measures the condition of the system, the experiment is over. Its condition is *this* former possibility—now certain. This process, says QM, done as often as one likes, defines the limits of reality.

Heisenberg, lord of the quantum netherworld, explains it in this way:

> The probability function can be connected with reality only if one essential condition is fulfilled: if a new measurement is made to determine a certain property of the system. Only then does the probability function allow us to calculate the probable result of the new measurement.

A measurement compels the system to pick one of the conditions that it could be in. In picking its reality it always plays the QM odds. Repeated, the ex-

periment will come up with each condition in accordance with those odds, like dice that show each side with odds of one in six.

The phone rings again. Just checking in, her voice says, which is most unusual. I tell her someone called here asking for an Adolf Hardin; for some reason Hardin is the name I say. She shrugs it off and asks what we are working on. Measurement—it is a problem, I explain. This too gets a shrug; or is it my imagination?

In my mind it is a growing problem. QM gives the system no reality outside of the experiment. Measurement, it says, is all there really is. To complicate things further, the results of the experiment are in what are called classical, non-quantum terms. For example, an experiment on the spin of an electron might use a pointer (QM is big on pointers). The pointer tilts to left or right to show the spin is up or down. QM calculates the probability that the experimenter will find the pointer in the LEFT state or the RIGHT. As Vigier expresses it, 'Quantum mechanics only concerns the statistical prediction of the results of well-defined experiments and nothing more.' In other words the odds of LEFTs and RIGHTs.

It puts me in mind of Plato. He tells a tale that's called the Allegory of the Cave. He speaks of a place—the *Cave*—where people, chained to face a wall, see on it only shadows of the real world behind them. For people, read physicists. For shadows, read measurements. How can they, with no more than the shadows and their own unfettered minds, transcend their bounds and see the real nature of their world? Some say it's wrong to even try.

Anyway, the instant the condition of a quantum system's measured it must pick a version of reality. Open the box and that cat is dead. Or not. The dead-or-not bit happens *when* the box is opened. This is the 'collapse' of the Wave Function. Whether the Wave Function really does collapse is controversial. Some versions of QM require it. Others don't.

Either way the Wave Function says nothing of what's going on. As Heisenberg says forcefully, there is no way to even talk about what happens between measurements. The concept of continuous reality is meaningless.

What does all this do for a detective? Well, if he should ask, I plan to quote Rovelli:

> Thus the picture of reality that emerges by taking quantum mechanics and general relativity seriously is quite radical: spacetime as a background 'entity' has fully disappeared. What the world is beyond these background regimes, and how we can describe, measure, or just think about it, are issues still immersed in a profound mystery.

I want to tell him: Listen to Rovelli. More than that I want to give him a good shake. He needs a different way of thinking: In the Beginning, measurement may

have no meaning because there won't be anything to measure and there won't be anything to measure it against.

He'll not come in this late. I return to Adolph Harvedin. But Google now gives me no hits. The URL is in my browser history but it too finds nothing. Yet his picture and that name were there!

A little later as I'm leaving a thought stops me: See no evil. I power up again; click Firefox, History; delete the URL.