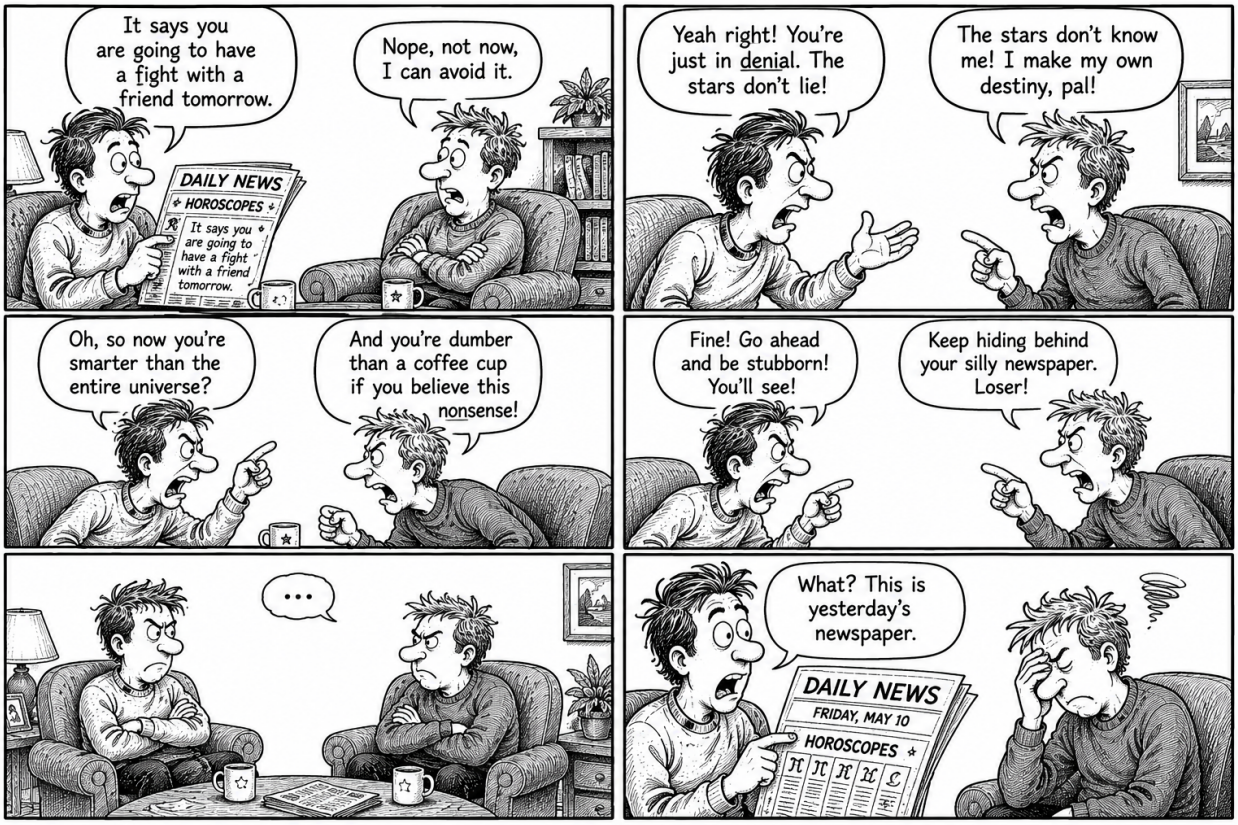
Chapter 12

"By Contradiction"



Horoscope

Reality – or So I'm Told

Quantum tic-tac-toe is a metaphor for superposition, one well suited to peel away some of the hidden assumptions that make quantum physics counter-intuitive. Despite the breadth and remarkable accuracy of quantum mechanics, the current formalism still suffers from unresolved fundamentals, and alone amongst modern theories, interpretational issues. We don't understand our own creation. It wasn't supposed to turn out this way.

In the 1920's a loose cadre of brilliant researchers cobbled together a theory of the very small, a theory with astonishing range and remarkable accuracy, but without an intuitive foundation. To use a modern term, quantum mechanics is a hack, a brilliant one, successful, highly useful, but one with interpretation problems no other theory has ever confronted. By brute force, a little trial and error, dogged persistence, and mathematical genius they built an edifice of sublime intricacy – if only we understood it. An architectural marvel; from the second story up.

Efforts to ground this edifice on a solid foundation keep running up against hidden assumptions. But how, exactly, does one go about questioning assumptions? Assumptions so basic, so fundamental, so ingrained in our mental processes, that we are completely oblivious to them.

And this is truly odd, because most of history's great breakthroughs required just that, identifying, and then replacing, obsolete assumptions, and many of these were required just to achieve the quantum mechanics we love and loath. At least we have a workable hack. Snide, derisive label that it is, it is no small accomplishment, hacks are hard, this one in particular. Our species is *good* at this. To quote the Klingons, "What is it that feeds our battle but starves our victory?"

Why can't we solve the measurement problem? Unsolved problems are not new, they are the lifeblood of science, but given unresolved fundamentals, how is it that the rest works at all? A sports car, with a powerful engine, is going nowhere without wheels to connect it to the ground. To mix metaphors, quantum mechanics has legs: Reality is laughing at us.

The first mission of this chapter is to enter the arcade of assumptions. It's a mess, no logical layout, no obvious place to begin. So, we start anywhere, no plan, just childlike curiosity. What is this place I find myself in?

Quantum Tic-Tac-Toe

"This place." Is that singular, or plural? When we look out into the World, we see *one* world. When we look out into the Universe, we see *one* universe. When we look at a game of Tic-Tac-Toe, we see *one* game of tic-tac-toe. When we see an effect, we look for a cause, and yes, when we see a cause, we hunt down its effect(s). But quantum mechanics mocks this commonsense view.

What does causality look like when it crosses worlds?

What does it mean to be in a superposition? Can we answer that question even in the simple, idealized case of one basis? One without complex weights? Just two equal magnitudes. It is the simplest possible superposition.

Superposition in quantum tic-tac-toe has a clear interpretation, that first move of two spooky marks implies we are now playing two games of classical tic-tac-toe at once, an ensemble of classical games. But the games in the ensemble are not independent, they are connected. How? What, exactly, connects them?

Somewhat subtly, it is the next move. The next move must be the *same* in every one of the games in the classical ensemble. This is what connects them, this is what binds them into an ensemble, and this is what leads to pruning by contradiction, for that one move does not have to be legal in *all* the games, just so long as it is legal in at least *two*.

For a moment, let's change one of the quantum rules, the collapse rule. Instead of collapsing to one game upon a cyclic entanglement, let both games continue, but now drop the requirement that the next move must be the same in both; allow the moves to be different. Now we are playing *two* quantum games, two independent games of quantum tic-tac-toe at once. This is the Many Worlds interpretation of quantum mechanics. The classical ensemble is a Many Realties metaphor, applicable *before* a measurement occurs. In the Many Worlds interpretation, the independent realities occur *after* a measurement happens. Note that this way of describing the Many Worlds interpretation denies that it is a solution to the measurement problem. Somehow, a measurement

must still happen, then and only then, do multiple independent universes sprout from one predecessor.

If this is a good metaphor for reality, we face a humbling possibility – we can't know which rule is in effect. Does the other game, the other universe, continue with a 'copy' of us in it, a separate independent instance of us? Or does only one instance persist? If realities cannot interact, the prospect for deciding between these two possibilities on scientific grounds looks forlorn.

In the Many Realities metaphor, each successive move doubles the number of classical games, duplicating the previous ensemble, then modifying each set; in one set goes the first spooky mark, in the other goes the second. This process is not guaranteed to be self-consistent, for it allows two marks in the same square, and this is not permitted in a classical reality – so it gets removed from the ensemble, ejected from reality, pruned from existence! An entire reality, or what we originally thought was a reality, is destroyed.

Intrepid Reader: take a moment to let the implication sink in. Under this metaphor, the Universe is a dynamic set of universes, duplicating what we thought was reality, moment to moment, then discarding others, pruned by contradiction. This is not the paradigm of classical physics, that is not what evolution has structured our brains to process, this is not what commonsense has programmed our minds to believe about the world.

'This place' is a very strange place.

Quantum Billiards

What do we mean by causality? What assumptions do we burden ourselves with when we invoke causality as an explanation for some effect?

Consider the game of billiards; one felt covered table, zero pockets, three balls, two players, two cues, one shared cube of chalk. What caused the first ball to move; it was struck by a cue stick. What caused the second ball to move; it was struck by the first ball. What caused it to change direction; it bounced off the cushion.

The goal is to change the position of all three balls. Hit this one, it hits that one, and either the first or second ball bumps into the third. These are our only options – at least in classical billiards.

What about quantum billiards? In virtual reality, such a game is almost trivial. Virtually, strike the first ball; it doesn't move – yet. Strike it again, from a different angle and viola, the table *duplicates itself and all its contents*, both struck balls begin to move, but in different directions on the two tables. Eventually, all six balls come to rest. To move them in each individual classical game required a sequence of causes. Let's emphasize that – on every single table (reality), to change the position of any ball, required cause by local contact, it required motion through space in time with a finite velocity. Energy, momentum, force, acceleration, friction; it's as classical as it gets. Is this the only way to change the locations of the billiards? Given only one table, that is the only option. In the classical case, change requires *impact*.

But this is a quantum game, with two tables, where superposition reigns. Assume for a moment that you can only look at one table at a time, but that you are always looking at a table. If the table

you are looking at is deleted, pruned from existence, some other one is presented to your view, holistically. What do you observe? Three billiards moved, *instantly*, without any contact, with infinite speed. In a word, nonlocally. What caused their positions to change? It wasn't an impact – the reality you thought you were in is gone, replaced by another. Note that this view is implicitly multivalued, it is inherently nonlocal, apparently random – the very hallmarks of quantum systems. It violates the classical concept of causality.

But perhaps we should not regard it as a violation, perhaps, it is a new type of causality, a type well suited for plurality, indeed, deeply coupled with it.

If one could select one reality out of many, then that selection would constitute a *cause* that affected the entire universe, in one fell swoop, from anywhere to everywhere, instantly, no local contact, not causality in any conventional sense whatsoever. Anything out of place jumps from one location to another, magically. Cosmic nonlocality.

It's as different from classical causality as it is possible to imagine. To grace it with the label *cause* is absurd, but something in our reality is nonlocal. Nature clearly does not allow us to choose a single reality out of many, but might she allow us to choose a *pair* of realties? Would she allow us to choose *half*? Or does she reserve the exclusive right to all choices? Have we no rights here?

Does she perhaps permit us to restrict her choices by causing situations that prune contradictory realities out of existence, so that regardless of her choice we are able to command outcomes that are subject to our will? Is this not in fact what we do when we choose to make a measurement in a particular basis? Are we co-creators of reality? How far will she let us go?

To this question we shall return.

Is this philosophy or physics? We now have in hand two examples, quantum tic-tac-toe and quantum billiards; one formally espoused, the other merely hinted at. However, two examples seldom seem compelling, as any two points define a line, a lineup of only two might be mere coincidence. However, if three points line up, then that is more indicative, more intriguing because the odds are lower. There is coincidence, and there is pattern.

How applicable is this idea of spooky-marks?

Quantum Othello

The game starts with an initial position of four stones, two white two black, in the center four squares: the two white stones on the diagonal, the two black stones on the anti-diagonal. Black moves first as in Go.

In the classical version of Othello®, Black has four possible first moves (by symmetry, only one). In the quantum version, he must choose two of them, a *spooky* move. There are therefore, six possible first moves in the quantum game (by symmetry, three). Two of them flip the *same* white tile, four of them flip *different* white tiles.

Figure 1 shows the classical ensemble for a game of quantum Othello after the first move where different white stones were flipped.

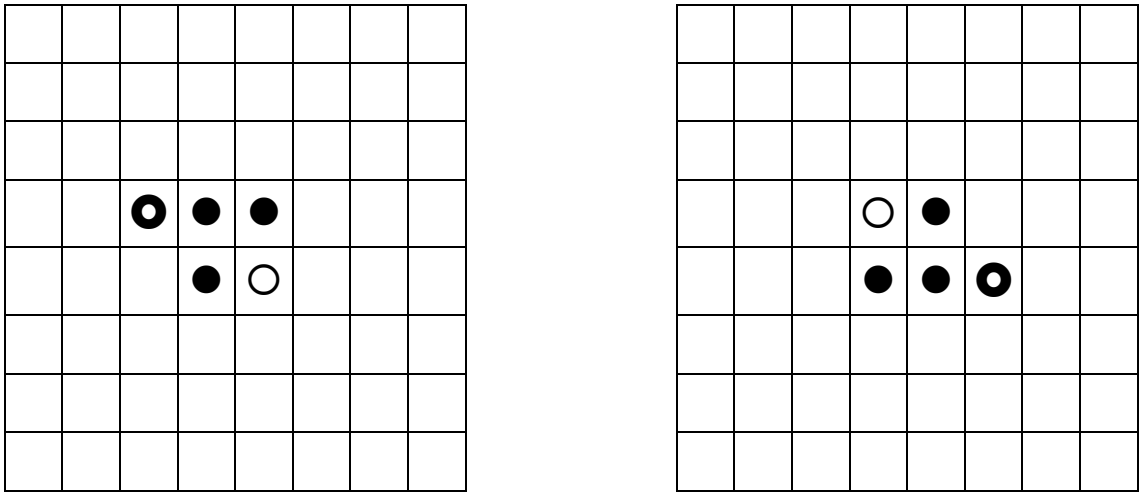


Figure 1 – **Quantum Othello**: Black makes a spooky move (⭘) that places the two pre-existing white stones into an EPR style entanglement; if one is black the other is white.

Call the two initially white stones A & B. In the first reality, A is black and B is white; in the second, A is white and B is black. Each has a 50/50 chance of being either color, yet neither has a definitive color all its own; it's color depends on the color of the other. They are entangled. Indeed, they are like an EPR pair, similar to one of the anti-symmetric Bell states, just without any phase.

$$\Psi_{AB} = \frac{1}{\sqrt{2}}\{|B_A|W\rangle_B \pm |W_A|B\rangle_B\} \quad (1)$$

Given a measurement, there are two metaphysical possibilities, either, these realities separate into their own independent quantum games, or one will be discarded and the other selected, but regardless, the colors of these two pre-existing stones will be *opposite*.

They are entangled, indeed, in a classical EPR style entanglement.

Sound familiar?

Quantum Games

In short order, we have found three examples of superposition in games, three colinear points if you will. Indeed, it looks like simple two-way superpositions are an easy way to turn conventional games into quantum games. Such games have common fundamentals; spooky moves expand upon the conventional moves (local causes), an ensemble of classical games connected by the next move (interpretation of superposition), and a new type of move (the collapse move). Games are pruned out of the classical ensemble by contradiction and by choice of collapse, both nonlocal causes.

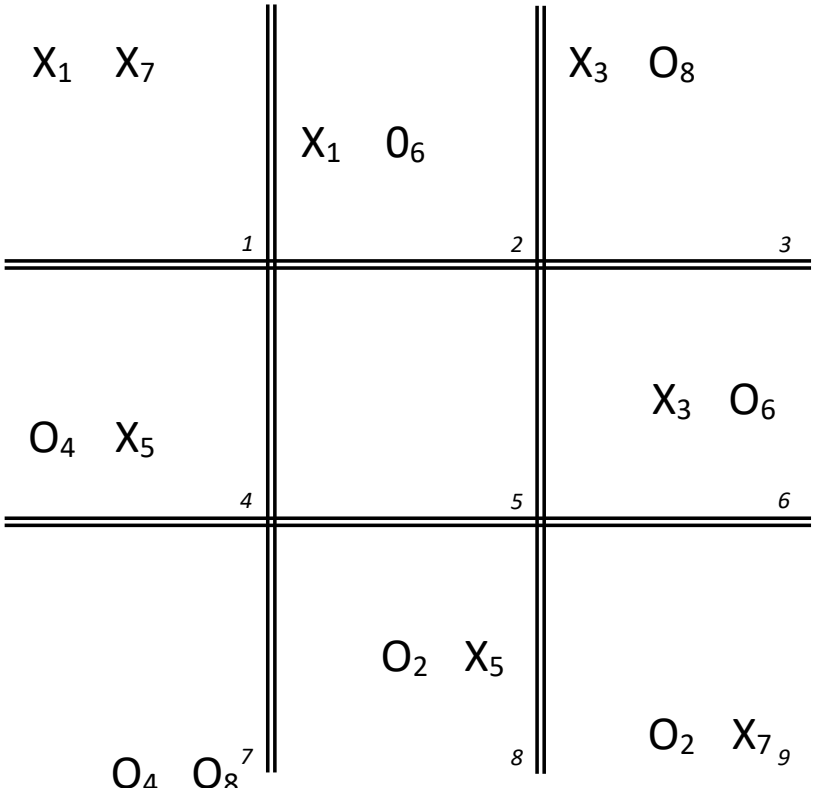
Such games can be used to question two of our most deeply buried assumptions; the world is single-valued, and all causes are local. Quantum realities violate both.

It worth emphasizing what is being argued here and what is not. Quantum games are not abstractions of reality, they are not idealizations, they are not approximations applicable to some range of phenomenon – they are an *intuition* tool, a means to identify hidden assumptions that (may) imply that the current formulation of quantum mechanics is a red herring. Some set of hidden assumptions is making it cognitively impossible to see the solution…thought experiment as paradigm penetrator.

FTL by Contradiction

Given the ease with which quantum games can be generated from classical games, we can assert some confidence in this class of metaphor. Therefore, let's analyze the FTL protocol developed by Reason in the discourse. This FTL scheme is predicated on the pruning of the classical ensemble, using quantum tic-tac-toe as a template. It is thus closely related to the concept of decoherence.

Figure 2 is a replica of Figure 4 from the previous chapter, but with one critical change; moves 7 and 8 are slightly different. They are still both in corner squares, but instead of being in the vertical columns, they are in the diagonal corners and anti-diagonal corners respectively. This changes the stats in the side squares.



Quantum

	X		O
1	1 2	**2**	9 8
3	3 6	**4**	7 4
5	4 8	**6**	6 2
7	1 9	**8**	3 7
9	– –		

Classical

	X		O
1	1	**2**	8
3	6	**4**	7
5	4	**6**	2
7	9	**8**	3
9	–		

Classical

	X		O
1	2	**2**	9
3	3	**4**	4
5	8	**6**	6
7	1	**8**	7
9	–		

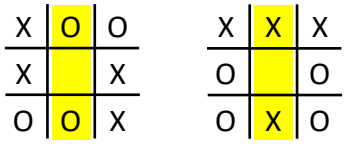


Figure 2 – **Alternate Last Moves**: The first six moves are the same as in Figure 4 of the previous chapter. In this metaphor, the corner squares are spacelike separated from the side squares. By changing the last two moves from *columns* (1,7 and 3,9) to *diagonals* (1,9 and 3,7), the statistics in the side squares change, each is still random, but the pairs 2 & 8 (in yellow), and 4 & 6, which were previously *anti-correlated* are now *correlated*. The randomness objection to FTL can be countered by correlating the noise across otherwise random channels.

In this metaphor, the corner squares are envisioned to be spacelike separated from the side squares. Each pair of spooky marks had a timelike genesis with respect to its destination squares. The sender (corner squares) has two options for creating a cyclic entanglement; either column corners (1,7 and 3,9) or diagonal corners (1,9, and 3,7).

The receiver (side squares) looks for correlations between pairs of side squares. Each side square is perfectly random, receiving equal number of X's and O's. There are three pairs:

2,4 & 6,8 – *Column* moves make these *correlated*, diagonal moves make these anti-correlated.

2,6 & 4,8 – In both cases, anti-correlated.

2,8 & 4,6 – *Diagonal* moves make these *correlated*, column moves make these anti-correlated.

The randomness objection, that nature can use nonlocality to achieve correlated noise over spacelike separations but prevent the sending of superluminal signals, applies to individual EPR pairs. However, more sophisticated entanglements may be possible that get around this objection. Each channel remains perfectly random, but how the cyclic entanglement is completed has the potential to correlate randomness *across* coupled channels thereby sidestepping this objection.

Of course, quantum tic-tac-toe is not a real quantum system, so the steps here may not map to physically realizable situations. But if they don't, that fact itself will reveal something about quantum physics.

Curioser and curioser.

Causality

Physics permits two types of causality – timelike and common cause. Within each classical reality, these function as they always have. But what kind of cause is it, when *deleting* a reality from the classical ensemble, leads to nonlocal correlations? This idea that superposition implies a classical ensemble of states, that this ensemble can be pruned in the lawful evolution of those states, is suggesting that our very definition of causality is incomplete.

Science fiction FTL is just spacelike causality, an unrestricted cause and effect between distant points. This is not what quantum nonlocality achieves, it is subtler, but it is some kind of causality, for the moment just call it a *third type* of causality and accept the ambiguity that we don't understand it – not yet.

This weakens the randomness objection.