Beyond Causality ... The Quantum Liberation[1]

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Quantum mechanics is the general theoretical framework of contemporary physics. At this point of time, one of the biggest open questions is: What, if anything, is quantum mechanics trying to tell us about the nature of Nature?

You may have heard claims to the effect that quantum mechanics supports a mystical world view. These claims (however valid they may be) are almost always made for the wrong reasons.

Quantum mechanics is a probability algorithm. It assigns probabilities to the possible outcomes of measurements that may be made on the basis of measurement outcomes that have been obtained. Notice the key role played by measurements. Quantum theory's invariable reference to "measurement" was famously criticized by John Bell:

> "To restrict quantum mechanics to be exclusively about piddling laboratory operations is to betray the great enterprise."

Unsurprisingly, physicists soon began to search for more respectable ways of thinking about measurements. Some called them "observations" and spoke of "the essential role played by the consciousness of the observer". This was in 1939.

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Today quantum mechanics is much better understood, and it is clear that the formidable challenge of making sense of the quantum world cannot be met in this cheap manner. Invoking consciousness like a *deus ex machina* is a gratuitous answer to a pseudoproblem that arises from false assumptions.

First I want to tell you about some of the fascinating implications of the quantum formalism, which one cannot see as long as one believes this red herring.

Then I want to tell you the real reason why measurements play a central role in the general theoretical framework of contemporary physics.

Then I want to tell you about the real problem caused by the fact that measurements play this central role, and how it can be solved.

Then I want to tell you about the pseudoproblems people are trying to solve instead, about the false assumptions from which they arise, and (if there is time) why it is so hard to get rid of them.

So let's get going. The single most important consequence of the way quantum mechanics assigns probabilities to the possible outcomes of measurements, is that it imposes limits on the distinctions that we are allowed to make.

Example: A metal plate with two slits, an electron gun in front, a screen behind. Wherever an electron hits the screen, it leaves a mark. If only the left slit is open, we see a certain distribution of marks. If only the right slit is open, we see a different distribution of marks. If both slits are open, anyone uninitiated into the mysteries of the quantum world expects to see the sum of these two distributions. What we actually see is completely different. The electrons behave as if each went through both slits. Since this is the behavior one expects from waves, electrons (as well as atoms, molecules, and bigger things) are said to behave in complementary ways (a euphemism for mutually inconsistent ways of thinking): sometimes like particles (we never see half an electron) and sometimes like waves. If we do not remain satisfied with mutually inconsistent ways of thinking about the same thing, we learn that quantum mechanics imposes limits on our *spatial* distinctions. The distinction we make between “electron goes through the left slit” and “electron goes through the right slit” is a distinction that Nature does not make. It corresponds to nothing in the real world. It exists solely in our heads.

This leads to the conclusion that the spatial differentiation of the physical world is incomplete. It doesn’t go all the way down. If we mentally partition the world into smaller and smaller regions, there comes a point when there isn’t any material object left for which these regions, or the corresponding distinctions, exist. Quantum mechanics is therefore inconsistent with the attempt to construct reality from the bottom up, by associating physical properties with the points of an intrinsically differentiated spacetime (the approach favored by contemporary philosophers of science).

Example: Two particles of the same type move towards each other, one (say) coming from the North, the other from the South. The next thing we know is that there are two particles moving away from each other, one eastward and one westward. Which is which? Is the one moving eastward the one that came from the North or the one that came from the South? Once again the quantum-mechanical probability assignments imply that we are making an illegitimate distinction, in this case an illegitimate *substantial* distinction.

We are allowed to distinguish between *this* particle and *that* particle only to the extent that particles have properties by which they can be distinguished, and they have such properties only to the extent that their possession can be inferred from the goings-on in the rest of the world. As a consequence, the so-called ultimate constituents of matter *considered by themselves*, independently of their measured properties (or independently of their spatial and dynamical relations—the things that can be measured), are identical not just in the weak sense of exact similarity but in the strong sense of *numerical* identity. If you have a particle here with these properties and a particle there with those properties, what you have is not two substances each with a set of properties (this is one “two” too many) but one substance with two sets of properties. Quantum mechanics is therefore equally inconsistent with the attempt to construct reality by assembling a pre-existent multitude of building blocks.

- The quantum world is built from the top down.
- What ultimately exists is a single substance. Call it whatever you like. (I like to call it *brahman*.)
- Both matter and space come into being when this enters into spatial relations with itself, for
- space is the totality of existing spatial relations, while
- matter is the corresponding apparent multitude of relata—*apparent* because the relations are *self*-relations.
- The form of any material object therefore consists of the spatial relations between the object’s parts, and
- objects without parts (like electrons) are formless.

The beasts and baubles of this world are not made of any kind of stuff. They are made of the fuzzy spatial self-relations of a single formless Reality.

Now, why are measurements so important? “Ordinary” objects

- have spatial extent (they “occupy” space),
- are composed of a (large but) finite number of objects without spatial extent (particles which do not occupy any space), and
- are stable: they neither explode nor collapse the moment they are formed.

These objects occupy as much space as they do because atoms and molecules occupy as much space as they do. So how is it that a hydrogen atom, composed of four objects without spatial extent (three quarks and one electron), occupies a space roughly one tenth of a nanometer across? Thanks to quantum mechanics, we now understand that the stability of matter rests on the *fuzziness* of the relative positions of its constituents. This is what "fluffs out" matter. The hydrogen atom is as big as it is because the position of the electron relative to the nucleus is as fuzzy as it is.

And what is the proper (mathematically rigorous and philosophically sound) way to describe a fuzzy position? It is to assign probabilities to the possible outcomes of a position measurement. This is the principal (albeit not the only) reason why our fundamental physical theory is a probability algorithm, and why it refers to measurements—not "piddling laboratory operations", not so much measurements that are actually made but *possible* measurements that are *not* actually made. (If we want to describe a fuzzy position without changing it, we must describe it by assigning probabilities to the possible outcomes of *unperformed* measurements.)

Next, the real problem caused by the fact that measurements play this central role.

A fundamental physical theory concerned with nothing but statistical correlations between measurement outcomes presupposes outcome-indicating events. How can such a theory be complete? How can it at the same time *encompass* these events?

This problem can be solved by a judicious reality assignment: which theoretical construct corresponds to what exists by itself (rather than *only* by virtue of being measured)?

- *Not* the so-called "quantum state", for that is a probability algorithm.
- *Not* the "manifold" of spacetime points, for the spatiotemporal differentiation of the quantum world doesn't go all the way down.
- *Not* the microworld, for its properties exist only to the extent that they are measured (that is, indicated by the goings-on in the macroworld).
- *But only* the macroworld, in which the outcome-indicating events occur.

The conclusion, once again, is that the quantum world is built from the top down. *The macroworld is not built out of the ingredients of a microworld. Instead, the properties of the microworld exist only because they are indicated by events in the macroworld.*

A few words about the place of causality in a quantum world.

- The laws of classical physics correlate states of affairs *deterministically*. Therefore they can be given a causal interpretation.
- The laws of quantum physics correlate measurement outcomes *statistically*. Therefore they *cannot* be given a causal interpretation.
- Planck's constant sets the scale of Nature's fuzziness. In the theoretical limit in which this approaches zero, the fuzziness disappears, and quantum physics degenerates into classical physics. Causal concepts are useful *only* in this classical limit.

Is this a problem? *Not if the Force at work in the world is an omnipotent force!* (There obviously is no need to explain the working of an omnipotent force.)

- The "state" of a quantum system is an algorithm that assigns probabilities to the possible outcomes of any given measurement *with the provision that* this measurement is successfully made.
- Since it is always assumed, the existence of an outcome cannot be explained. *Measurement outcomes are uncaused.*

Now I can tell you what pseudoproblems people are trying to solve. To begin with, they of course want to explain why measurements have outcomes. In the quantum world, this is as impossible as it is to explain why there is anything at all, rather than nothing.

To understand more, we first need to separate the facts of *classical* physics from its fictions.

Newton found an algorithm that allows us to calculate the gravitational effects of matter on matter. He also famously refused to make up a story purporting to explain how, by what mechanism or process, matter acts on matter.

While the (Newtonian) gravitational action of one object on another depends on the *simultaneous* positions of the two objects, the electromagnetic action of matter on matter is retarded: effects are later than their causes. This made it possible to transmogrify the *algorithm* for calculating the *electromagnetic* effects of matter on matter into a *mechanism or physical process* by which matter acts on matter.

Later Einstein's theory of gravity made it possible to also transmogrify the algorithm for calculating the *gravitational* effects of matter on matter into such a mechanism or process.

- *Fact* is that the calculation of electromagnetic effects can be carried out in two steps: given the distribution and motion of electrically charged objects, we calculate six functions (the so-called "electromagnetic field"), and given these six functions, we calculate the electromagnetic effects that these objects have on other charged objects.
- Much the same goes for the calculation of gravitational effects: given the distribution and motion of matter along with those six functions, we calculate the so-called stress-energy tensor, and given this, we calculate the curvature of spacetime, which is Einstein's way of describing gravitational effects.
- *Fiction* is that the electromagnetic field is a physical entity in its own right; that it is *locally* generated by charges *here*, that it mediates electromagnetic interactions by *locally* acting on itself, and that it *locally* acts on charges *there*. ("Locally" means that the action happens at one and the same place.)
- Another fiction is that spacetime curvature is a physical entity in its own right, and that it mediates the gravitational action of matter on matter by a similar local process.

Here is one of my favorite quotes (B.S. DeWitt and R.N. Graham):

> "Physicists are, at bottom, a naive breed, forever trying to come to terms with the 'world out there' by methods which, however imaginative and refined, involve in essence the same element of contact as a well-placed kick."

Did you notice that those fictions do *not* explain how a charge locally acts on the electromagnetic field, how the electromagnetic field locally acts on a charge, etc.? Apparently, physicists consider the familiar experience of a well-placed kick sufficient to explain local action!

Back to *quantum* physics:

- At bottom, both classical states and quantum states are probability algorithms.
- Because a classical state only assign trivial probabilities (0 or 1), one can get away with re-interpreting it as an actual state of affairs, even though this involves the transmogrification of mathematical algorithms into physical mechanisms.
- Because a quantum state assigns genuine probabilities (anything between 0 and 1), it is not possible to re-interpret it as an actual state of affairs or to transmogrify its time-dependence into a physical process.

If you try to do this all the same, you are up against the fact that an algorithm for assigning probabilities to the possible outcomes of a later measurement, on the basis of the outcome of an earlier measurement, depends not only continuously on the time of the later measurement but also discontinuously on the outcome of the earlier measurement. If you want to transmogrify a quantum state into a physical entity in its own right, you must explain why it changes (or appears to change) continuously between measurements and discontinuously at the time of a measurement. This is *the mother of all quantum-mechanical pseudoproblems*.

Why is it so hard to disabuse physicists of their futile efforts to construct the quantum world from the bottom up, on the basis of an intrinsically differentiated spacetime, and to construe the quantum-mechanical correlation laws as some local, continuous, physical process, despite many rigorous proofs (starting with Bell's theorems in the 1960's) that this is strictly impossible?

For one thing, the theoretical physicist's toolbox is mathematics. Mathematics is the mental activity *par excellence*. The single most basic mathematical concept is that of a set, defined by the creator of set theory as "a Many that allows itself to be thought of as a One".

The quantum world, on the other hand, is a One that allows itself to be thought of as a Many. (Remember: matter and space come into being when *brahman* enters into spatial relations with itself, for space is the totality of existing spatial relations, while matter is the corresponding apparent multitude of relata—*apparent* because the relations are *self*-relations.)

For another thing, the construction of the *phenomenal* world (by our minds and brains) rests on *surfaces*. It is therefore natural for us to believe that the shapes of things are surfaces, and that the parts of things are defined like the parts of space, by boundaries. Once we permit ourselves to think of "parts of space", we end up thinking that space consists of infinitely many infinitely small parts ("points"), and that the spatial differentiation of the world is complete.

The construction of the *physical* world is an altogether different kettle of fish. It rests on fuzzy spatial relations between formless objects, rather than surfaces. The shapes of things are sets of spatial relations between formless objects, rather than surfaces. Because these relations are fuzzy, the spatial differentiation of the world is incomplete; it doesn't go all the way down.

So there are fundamental differences between the ways in which the two worlds—physical and phenomenal—are constructed, and this more than anything else is responsible for the deep-seated misconceptions about space and matter, which make it so hard to beat sense into quantum mechanics.

There is a yet deeper reason. The brain works the way it does because mind works the way it does, rather than the other way around, as we are prone to think. The real culprit is not the brain, which is instrumental in the construction of the phenomenal world, but the mind.

The difference between those two worlds reflects a difference between the consciousness creative of the physical world (*supermind*) and the consciousness creative of the phenomenal world (*mind*). The action of supermind is primarily qualitative and infinite and only secondarily quantitative and finite. Mind in its essence is the agent of this secondary, quantifying, and delimiting action.

When mind is employed by supermind (as it is in the creation of the physical world), its tendency to divide *ad infinitum* is checked. This is why quantum mechanics imposes limits on the reality of our distinctions.

When mind is effectively separated from its supramental parent and left to run wild (as it is in us), it not only divides *ad infinitum* but also takes the resulting multiplicity for the original truth or fact. This is the real reason why we want to construct reality from the bottom up, and why it's so hard to understand the quantum world.

Einstein used to insist that things can "claim an existence independent of one another, insofar as these things 'lie in different parts of space'." This claim is utterly inconsistent with the quantum theory. In the quantum world, we may think of space either as an *undifferentiated* expanse, in which case there are no different parts of space, or we may think of space as the totality of spatial relations between *brahman* and *brahman*, in which case things cannot claim an existence independent of one another. Einstein's insistence is a perfect illustration of the mental outlook, for, in Sri Aurobindo's words (*The Life Divine*, 1987, p. 162), "mind in its essence is a consciousness which measures, limits, *cuts out* forms of things from the indivisible whole and contains them as if each were a *separate* integer.... It conceives, perceives, senses things *as if rigidly cut out from a background or a mass*." Observe the importance of delimiting surfaces.

As said, in the quantum world, the modern concept of causality, which corresponds to Aristotle's *efficient* causes, is useless. On the other hand, Aristotle's concept of *final* causes, which explain what something is good for, still works. For instance, as we have seen, fuzzy spatial relations are needed for the existence of objects that have spatial extent, are composed of finite numbers of objects without spatial extent, and neither explode nor collapse the moment they are formed.

The following questions can be answered in the same way:

- Why does the Force at work in the world subject itself to correlation laws? *In order to set the stage for the Adventure of Evolution.*
- Why these particular correlation laws? *Because it's the only way to do that.*

To be more precise:

- Evolution presupposes involution.
- When involution is complete and the stage is set for the drama of evolution, all that exists is fuzzy spatial relations, formless relata ("particles"), and the quantum-mechanical correlation laws, which presuppose the existence of measurement outcomes.
- In order to be consistent with the existence of measurement outcomes, the correlation laws must be consistent with the existence of measuring instruments.
- It can be shown that, in order to be consistent with the existence of measuring instruments, the *relevant* correlation laws—those that are relevant at available energies or accessible scales—must have precisely the form that they do.

Afterthoughts:

- Dualist philosophers of mind, claiming that mind and matter are mutually irreducible, are often criticized for failing to explain how a nonmaterial mind can act on matter. These critics must be reminded that physicists are not in a position to explain how matter acts on matter. All they can do is, classically, calculate the effects of matter on matter and, quantum-mechanically, calculate probabilities of measurement outcomes.
- Physicists can no longer equate any of the mathematical symbols of their formalism to matter. Matter has slipped through their fingers. The physical basis of materialism is gone.

Note: A PowerPoint presentation with the same title as this talk (and similar content) can be downloaded from `www.ThisQuantumWorld.com`.