

# Beyond the Central Dogma of Physics

*The universe is one manifesting itself in multiplicities that behave according to certain mathematical rules; but this leads to paradox as soon as we think of the underlying reality as if the multiplicities were real (see Quantum World Coming series, Science in Society 22)*  
**Ulrich Mohrhoff** argues for the fundamental unity of nature that avoids asking what he says are pseudo-questions

*Niels Bohr, Werner Heisenberg and Wolfgang Pauli*



## The evolutionary paradigm

Mae-Wan Ho has written eloquently against the Central Dogma in biology (Life After the Central Dogma of Biology series, *Science in Society* 24; Living with the Fluid Genome, ISIS publication). In physics, too, there is a Central Dogma, which I have dubbed 'the evolutionary paradigm'. It is the notion that physics can be neatly divided into a *kinematical* part, which concerns the description of a physical system at an instant of time, and a *dynamical* part, which concerns the evolution of a physical system from earlier to later times.

The laws of physics are correlation laws. In classical physics, states are correlated deterministically, so earlier states can be used to predict later states (and later states can be used to retrodict earlier states). Quantum physics correlates measurement outcomes statistically, so earlier measurement outcomes can be used to predict the probabilities of the possible outcomes of later measurements (and later measurement outcomes can be used to retrodict the probabilities of the possible outcomes of earlier measurements). Because the quantum-mechanical correlation laws are genuinely probabilistic, they may not conform to the evolutionary paradigm.

And they don't. For one thing, the time-symmetry of the laws of physics is at odds with the unidirectionality of the evolutionary paradigm, which has its roots in a physically unwarranted projection into the world of the way we perceive the world. (This casts doubt on the appropriateness of the evolutionary paradigm even for classical physics.) For another thing, the interpretation of a quantum state as an evolving physical state (rather than as a mere computational device) gives rise to no end of pseudo-questions (and gratuitous answers), such as the notorious questions of where and when and how (and with respect to which basis) the wave function collapses (see Nature is Quantum, Really, *SiS* 22).

Owing to the Central Dogma, the wave function is widely regarded as the primary affair. This has led to the belief that the probabilities of possible measurement outcomes are *absolute*, determined by a system's evolving quantum state, rather than *conditional*, determined by actual measurement outcomes via computational devices called "quantum states". Nobody has seen this more clearly than the late Asher Peres, who insisted that, "there is no interpolating wave function giving the 'state of the system'

between measurements." In dealing with quantum mechanics, we constantly ought to remind ourselves that the state of a system between measurements is unobservable *by definition*.

In the classical limit, the quantum-mechanical probability calculus degenerates into a classical probability calculus rather than a description of physical reality. Because the classical calculus is trivial, in the sense that it only assigns the probabilities 0 or 1, it is possible to interpret it as representing an evolving physical state, rather than as being an algorithm for assigning probabilities to possible measurement outcomes. Because quantum-mechanical probabilities fill the entire range from 0 to 1, it is *not* possible to think of the state vector as representing an evolving physical state, at least not without generating pseudo-problems and absurd solutions. The time dependence of a quantum state is not that of an evolving physical state but the dependence of an algorithm on the time of *the measurement* to the possible outcomes of which it serves to assign probabilities.

## The Central Dogma sweeps the real problem under the rug

The Central Dogma bamboozles us into believing that to solve the so-called measurement problem "means to design an interpretation in which measurement processes are not different in principle from ordinary physical interactions," as an anonymous referee once put to me. This sweeps the real problems under the rug. All we know about "ordinary physical interactions" is through correlations between the probabilities of measurement outcomes. The real problems are:

1. Why is the fundamental theoretical framework of contemporary physics a probability calculus? And why are the events whose probabilities it serves to calculate, measurements?
2. What can we conclude about Nature by analysing quantum-mechanical probability assignments?
3. How can we rigorously define "macroscopic"?
4. Which substructure of the quantum-theoretical 'universe of discourse' corresponds to reality?
5. How can we understand the supervenience of the macroscopic on the microscopic, i.e., the fact that the microworld is what it is because of what happens in the macroworld, rather than the other way round as we are wont to think?

### The universe is objectively fuzzy

The reason why the fundamental framework of contemporary physics is a probability calculus is an objective fuzziness. (The proper way of defining and quantifying the objective fuzziness of the quantum world is to assign probabilities to possible measurement outcomes on the basis of actual outcomes.) This objective fuzziness makes possible the existence of macroscopic objects, i.e., objects that have spatial extent (they 'occupy' space), appear to be made of finite numbers of particles without spatial extent, and are stable, i.e., they don't collapse or explode as soon as they are created. Quantum fuzziness thus is a precondition of macroscopic objects, whose existence in turn is required for the consistency of quantum mechanics.

### Nature makes fewer distinctions than we do

The general conclusion about Nature is that whenever quantum mechanics instructs us to calculate the probability of a given outcome by adding the amplitudes (rather than the probabilities) of a set of alternatives, the distinctions we make between the alternatives are distinctions *that Nature does not make*; they correspond to nothing in the real world; they exist solely in our heads.

Suppose that we perform a series of position measurements, and that every position measurement yields exactly one outcome (i.e., each time exactly one detector clicks). Then we have a conservation law, and we are entitled to infer the existence of an entity which persists through time, to think of the clicks given off by the detectors as indicating the successive positions of this entity, to think of the behaviour of the detectors as position measurements, and to think of the detectors as detectors. What if each time exactly two detectors click? If there isn't another conservation law effectively providing the entities with identity tags, then there is no answer to the question of which particle is which. The question is meaningless.

Now consider a particle lacking internal relations. What is it 'in itself', out of relation to its external relations? The answer is "nothing", except possibly a substance lacking properties. For the measurable properties of particles are either kinematical relations such as positions or momenta, or parameters characterizing dynamical relations such as the various kinds of charge, or they have an objective significance independent of conventions only as dimensionless ratios.

According to a philosophical principle, the identity of indiscernibles, *A* and *B* are one and the same thing just in case there is no difference between *A* and *B*. Not only is there no difference between two particles lacking internal relations considered 'in themselves', but nothing real corresponds to the distinction we make between *this* particle and *that* particle over and above the distinction between *this* property and *that* property. What follows from this is the *numerical identity* of all particles lacking internal relations, considered by themselves. If we think of particles lacking internal relations as the 'ultimate constituents of matter', then there is a clear sense in which the number of 'ultimate constituents of matter' equals 1.

Thus a quantum system is always *one*. It is a single substance, the number of its 'constituents' simply being one of its measurable properties. And its 'ultimate constituents', considered by themselves, are identical in the strong sense of numerical identity. If I now permit myself to think of the entire physical world as a quantum system and ask about its constituents, I find that there is just one, a single intrinsic substance without properties. This single substance gives rise to the totality of more or less fuzzy spatial relations we call "space", and it gives rise to the corresponding apparent totality of relations we call "matter", apparent because the relations are *self-relations*.

### Defining macroscopic

Whereas no object ever has a sharp position (relative to any other object), some objects have the sharpest positions in existence. (In a non-relativistic world this is so because the exact localization of a particle implies an infinite momentum dispersion and hence an infinite mean energy. In a relativistic world the attempt to produce a strictly localized particle results instead in the production of particle-antiparticle pairs.)

The possibility of obtaining evidence of the departure of an object from its classically predictable position calls for detectors whose position probability distributions are even narrower than that of the object to be probed. Such a detector is unlikely to exist, and hence the probability of obtaining evidence of departures from the classically predictable motion is very low. Consequently, among such objects, there will be many of which the following is true: *every one of their indicated positions is consistent with every prediction that can be made on the basis of previously indicated properties and a classical law of motion*. These are the objects that deserve to be labelled 'macroscopic'. To permit a macroscopic object to indicate a measurement outcome, one exception has to be made: its position may change unpredictably if and when it serves to indicate an outcome.

### Quantum theory and reality

The substructure of the quantum-theoretical 'universe of discourse' that corresponds to reality is the *macroworld*, defined as the totality of relative positions existing between macroscopic objects, 'macroscopic positions' for short.

The reason why it is legitimate to attribute to the macroworld - not individually to each macroscopic position but to the macroworld in its entirety - a *free-standing* reality, i.e., a reality independent of anything external to it, is that, by definition, macroscopic positions are not *manifestly* fuzzy. For the supervenience of the macroscopic over the microscopic (i.e., the fact that the microworld owes its properties to events that happen in the macroworld) is a consequence of the fuzziness of the microworld. If all measurable quantities were in possession of sharp values at all times, we could think of all measurements as revealing pre-existent properties. It is the objective fuzziness of the microworld that compels us to think of quantum measurements as *creating* their outcomes rather than revealing pre-existent properties. And it is the macroworld's lack of manifestly fuzzy properties (i.e., the fact that, by definition, its properties never evince their fuzziness) that permits us to think of the macroworld as a free-standing reality.

### Whence the dependence of the microworld on the macroworld?

A twenty-five centuries old paradigm thus has passed its expiry date. It is no longer appropriate to ask, what are the ultimate constituents, and how do they interact and combine? Ultimately there exists One Being. Call it whatever you like. What constitutes the macroworld is not the 'microworld' but the single substance without properties that, by entering into spatial relations with itself, gives rise to both matter and space.

The manifested world is the macroworld. The 'microworld' is neither a world nor a part of any world but *instrumental* in the manifestation of the (macro)world. Quantum mechanics affords us a glimpse 'behind' the manifested world. But, and this is the punchline, we cannot describe what lies behind the manifested world except in terms of the finished product, the manifested world.

Imagine that you experience something the like of which you have never experienced before. How are you going to describe it? You are obliged to use words that refer to experiences you have had. It is the same with the manifestation. Only, in this case, it is not merely the words but the properties that are missing. The

microworld does not *have* properties; it *gives* properties. It is instrumental in manifesting the properties of the (macro)world.

### The two other faces of reality

As said, ultimately there is a One Being. This manifests itself, and quantum mechanics tells us how. But it does not only manifest itself. It manifests itself *to itself*. It is not only that *by* which the world exists but also that *for* which the world exists. In other words, it is not only the substance that constitutes the world but also the consciousness that contains it. In addition, that One Being is, subjectively speaking, an infinite bliss and, objectively speaking, an infinite quality infinitely expressing and experiencing itself.

This is the core of the ancient Indian theory of existence known as Vedanta, which describes ultimate reality in terms of its threefold relation to the world, as *sat-chit-ananda* or substance-consciousness-bliss.

Why does *sat-chit-ananda* hide in particles that, individually, lack spatial extent? Why does it subject their relations to apparently self-effective laws? In this world, *sat-chit-ananda* is playing Houdini, imprisoning and enchaining itself as rigorously as it can, challenging itself to escape, to re-discover and re-affirm its powers in what seems to be a universe of mechanical forces and random events. A multiple exclusive concentration allows it to enter various states of ignorance and incapacity so as to experience growth in knowledge and power, the excitement of conquest and discovery, the surprise of the unknown, the challenge of opposition, the triumph of victory.

Because quantum mechanics presupposes macroscopic objects, its consistency requires the existence of macroscopic objects. And it is eminently plausible that this in turn requires the validity of all empirically tested physical theories, the Standard Model and general relativity.

This is a humbling conclusion, for it means that all empirically tested physical theories are essentially tautological. If you want spatially extended objects that neither explode nor collapse the moment they are formed, the validity of these theories is a must. To be precise, their validity is guaranteed *if* spatially extended objects are composed of objects that lack spatial extent. This is the sole non-trivial input and the only real mystery. Why are things that 'occupy space' made of finite numbers of things that don't?

This, too, can be understood. The creation of a world of unextended particles can be seen as the final stage of an involution that has set the stage for the adventure of evolution.

### Critique of the conventional paradigm in statements made by Ho

The perspective I have presented chimes in with what Mae-Wan Ho wrote in her Quantum World Coming series (SiS 22): "The greatest gift of the quantum age is a truly organic way of living and perceiving the world that will reconnect western science to the deeply ecological and holistic knowledge systems of all indigenous cultures. It will make us realise how urgently we need to protect and revitalize these traditional knowledge systems as the real 'common heritage' of the human species."

But I disagree with some of her statements, especially those that are well established in both the professional and the popular literature on the subject (and she has indeed gone on to contradict some of them in her articles).

For example, in *Nature is Quantum, Really* (SiS 22), she refers to "the weird and wonderful world of quantum systems ... in which 'things' are both wave and particle, and can be in two places or multiple, contradictory states at the same time."

A 'thing' is a particle only in the sense that a position can be attributed to it, if and when, and to the extent that is measured. The wave in question is nothing but a feature of a quantum-mechanical probability algorithm. Interference phenomena reveal features of that

algorithm, not features of the 'thing'. A thing can be in two places in the sense that the probability of finding it here and the probability of finding it there are both greater than 0; but the distinction we make between 'the thing here' and 'the thing there' is one that Nature does not make; it corresponds to nothing in the real world; it exists solely in our heads.

It is misleading to say that a thing is *in* a (quantum) state, though of course we often do, for a quantum state is nothing but an algorithm giving the probabilities of the possible outcomes of possible measurements.

In *How Not to Collapse the Wave Function* (SiS 22), Ho writes: "In the standard quantum theory, a quantum system is in a superposition of states or in quantum entanglement, which is invariably destroyed by measurement."

This suggests that a superposition of states is the same as quantum entanglement. A (pure) state plays two rôles: it can be the probability algorithm associated with a quantum system, and it can represent a possible measurement outcome (for the purpose of calculating its probability). When a (pure) state, which is a vector, is written as a linear combination of other vectors, then it is a probability algorithm, while the other vectors represent possible measurement outcomes. Quantum entanglement is a possible feature of the state of a composite system. Neither a superposition of quantum states nor quantum entanglement is something that can be destroyed, inasmuch as one cannot destroy a probability algorithm. One can only update it with newly acquired information. This typically renders previously relevant information irrelevant.

Later in the same article, Ho states that, "when one particle is measured to have a certain property, then the corresponding property of the other particle is instantaneously determined." When one of two particles 'in' an entangled state is subjected to a measurement, information is obtained that is relevant to the probabilities of the possible outcomes of most measurements to which the other particle may be subjected. No property of the other particle is thereby determined. Only the probabilities of the possible outcomes of measurements are affected.

A related criticism can be levelled against her statement in *Quantum Phases and Quantum Coherence* (SiS 22): "...why, if nature is fundamentally quantum mechanical, do we see it predominantly as classical in our everyday life? That is because a quantum system enters into quantum entanglement with the observer."

Saying that a quantum system enters into quantum entanglement with another quantum system is the same as saying that the appropriate algorithm for calculating the joint probabilities of the possible outcomes of joint measurements (one performed on each system) ceases to be a direct product of independent algorithms (one for each system). If two quantum systems are entangled, the outcome of a measurement performed on either system contributes to determine the probabilities of the outcomes of most measurements that may be performed on the other system. Hence if it were appropriate to treat a measurement apparatus ('observer') as a quantum system entangled with an 'observed' system, there would be no measurement. The entanglement would only make it possible to learn something about the 'observed' system by subjecting the apparatus to a measurement, which calls for another measurement apparatus, which gets entangled with the first, and so on *ad absurdum*.

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