Spiritual Physics

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> I think it is safe to say that no one understands quantum mechanics.
> — Theoretical physicist Richard Feynman (1967)

> The theory has, indeed, two powerful bodies of fact in its favour, and only one thing against it. First, in its favour are all the marvellous agreements that the theory has had with every experimental result to date. Second, it is a theory of astonishing and profound mathematical beauty. The one thing that can be said against it is that it makes absolutely no sense!
> — Mathematical physicist Sir Roger Penrose (1986)

Quantum mechanics (QM, also known as quantum physics and quantum theory) is the fundamental theoretical framework of contemporary physics. What does it tell us about the physical world? The answer depends on your metaphysical presuppositions.

Science operates within an interpretative framework that formulates questions and interprets answers. This interpretative framework is not testable by scientific methods. The "bare" empirical data are consistent with a variety of such frameworks. (The scare quotes serve as a reminder that there really is no such thing as a bare, uninterpreted datum.)

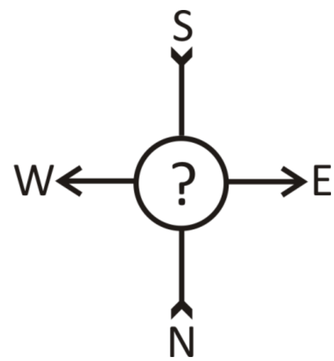
The mathematical formalism of QM is a collection of algorithms (computational tools). You may think of these algorithms as machines with inputs and outputs. You insert…

- a mathematical representation of a measurement M that you intend to make,
- the time of M,
- and mathematical representations of some or all of the relevant measurement outcomes previously obtained,

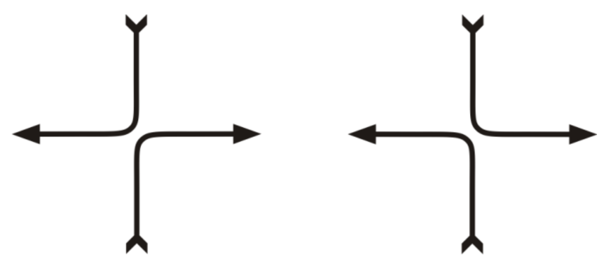
…and out pop the probabilities of the possible outcomes of M. Barring technicalities that are irrelevant for the purpose of this lecture, this is all there is to it! The rest is metaphysical embroidery.

Why is the fundamental theoretical framework of physics concerned with *measurements* of physical quantities, like position or energy, rather than the physical quantities themselves? Why does it let us predict the *probabilities* of the possible outcomes of a measurement but not the actual outcome? Few physicists or philosophers of science believe that they have the answers, and fewer still believe the answers that have been proposed. This state of affairs is reflected in the statements by two eminent physicists quoted above.

Equally disconcerting are the probabilities that QM assigns to the possible outcomes of measurements. As our first example, we will consider the following scattering experiment. Initially we have one particle (N) heading in a direction we call "northward" and one particle (S) heading southward. The next thing we know is that we have again two particles, one (E) heading eastward and one (W) heading westward. Which outgoing particle is identical with which incoming particle?



If the particles carry "identity tags" — for instance, if they are of different types and no "type swapping" takes place — then obviously there is an answer: either E is the same as S and W is the same as N, or E is the same as N and W is the same as S:



But if the particles lack "identity tags" — i.e., if they lack properties by which they could be distinguished — then there is *no answer*. The reason this is so is that the very assumption that what *really* happens corresponds to either of the above diagrams, is at odds with what QM predicts. The question "Which incoming particle is identical with which outgoing particle?" is meaningless.

Here as elsewhere, the challenge is to think in ways that do not lead to meaningless questions. Meaningless questions arise from false assumptions, in this case the assumptions that

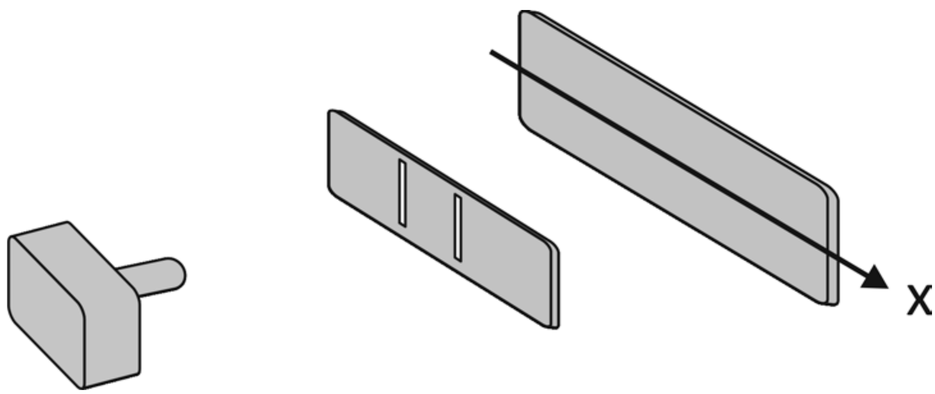
- initially there are *two* things, one moving northward and one moving southward,
- in the end there are *two* things, one moving eastward and one moving westward.

"Obvious" though they may be, if we make these assumptions, we are led to ask the meaningless question: which outgoing particle is identical with which incoming one? If, on the other hand, we assume that

- initially there is *one* thing moving *both* northward *and* southward,
- and in the end there is *one* thing moving *both* eastward *and* westward,

then the meaningless question — "Which is which?" — does not arise. If these are the correct assumptions — and there are other experimental scenarios and aspects of QM that support this conclusion — then ultimately there is only one "thing." By taking on distinct properties, such as being in different places or moving in different directions, this appears to be — or manifests itself as — a multitude of things, but the underlying substance — what ultimately exists — is *one*.

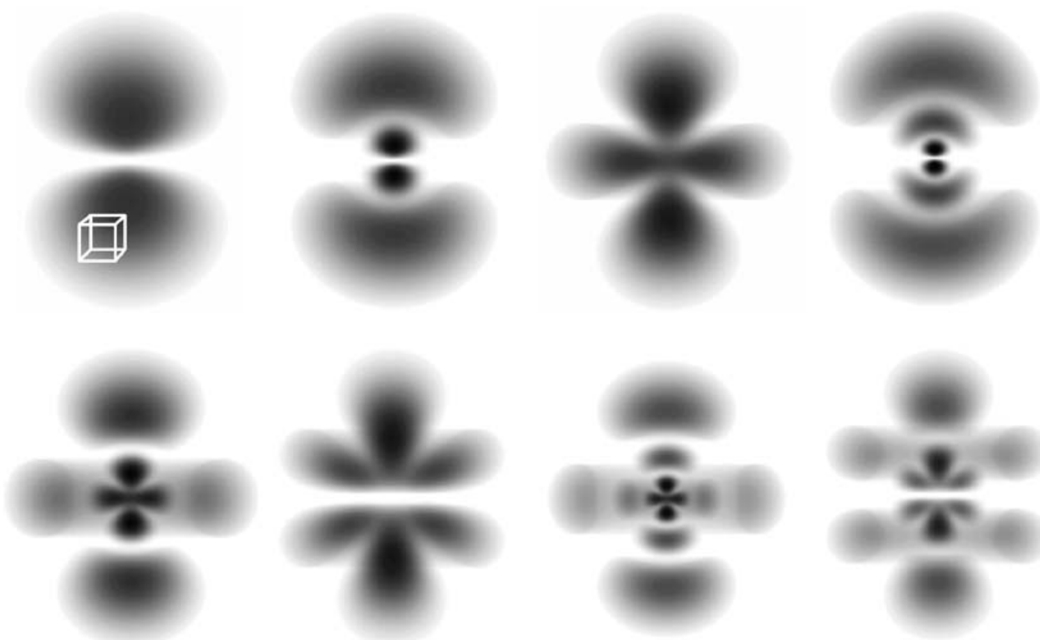
While the above scenario bears on the concept of *substance*, the following experiment throws light on the nature of *space*. An electron is launched in front of a plate with two slits. The next thing we know is that it is detected at the backdrop at a particular horizontal position x.



Here the million-dollar question is: through which slit did the electron go? If there is *anything* —any event or state of affairs — from which the answer can be inferred, then obviously there is an answer. But if there is no such event or state of affairs, then there also is *no answer*. Once again we are asking a meaningless question. This time it involves the false assumption that the electron necessarily goes *either* through the left slit *or* through the right slit.

To see why this assumption is wrong, let us contemplate the images on the following page. Each of them "shows" the fuzzy position of the electron relative to the nucleus — a proton — in a stationary state of atomic hydrogen. (Neither the proton nor the electron is shown; all you see is fuzzy relative positions.)

Explanation: A (quantum) *state* is one of the aforementioned probability algorithms. As you will remember, every quantum-mechanical probability algorithm depends on the outcomes of previous measurements. In this case three quantities were measured: the atom's energy, its total angular momentum, and the vertical component of its angular momentum.

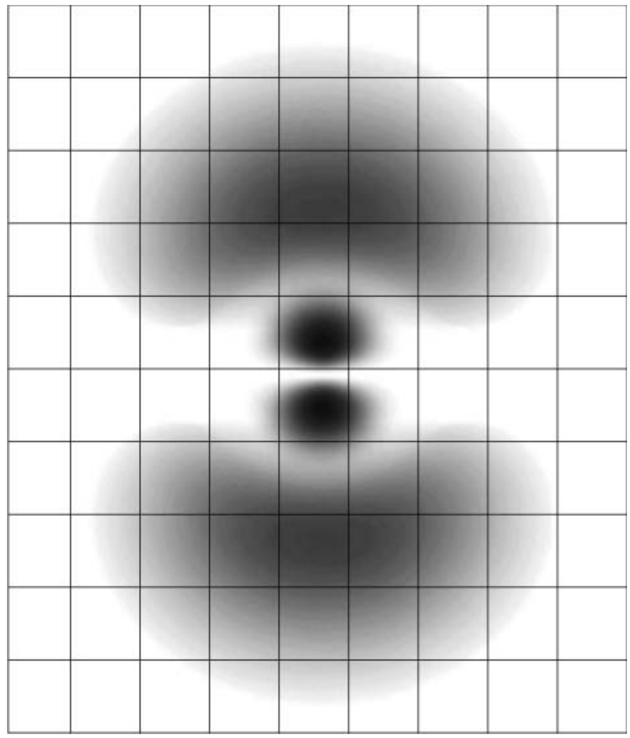


The outcome of the latter quantity was zero in each case. In the first row, the total angular momentum (in suitable units) was found equal to 1, 1, 2, and 1, respectively; in the second row, it was found equal to 2, 3, 2, and 3. A (quantum) state is *stationary* if the probabilities it assign to the possible outcomes of any future measurement do not depend on the time at which this is performed. In a stationary state, the possible outcomes of an energy measurement form a discrete sequence; they can therefore be labeled by the "principal" quantum numbers N = 0, 1, 2,... In the first row, the values of N were found to be 2, 3, 3, and 4; in the second row, they were found to be 4, 4, 5, and 5.

The images themselves represent something that (i) has a rotational symmetry about the vertical axis and (ii) can obviously be described as "fuzzy." But in what sense can a *relative position* be described as fuzzy? And how can a fuzzy relative position be defined in quantitative terms?

Embedded in the first fuzzy image is a small cube. If the image represented the variable water density (mass of water per unit volume) of an actual cloud, integrating it over the cube would yield the total mass of the water contained in the cube. What the image actually represents is a variable "probability density": integrating it over the cube yields the probability of finding the electron inside the cube, provided that the appropriate measurement is made. The proper definition (as well as description) of the fuzzy position of a particle thus is an algorithm that yields the probability of finding the particle in any given region (again, provided that the appropriate measurement is made).

Now take a look at this image:



If we conceptually divide the space "occupied" by this probability "cloud" into different regions — for simplicity's sake we here ignore one spatial dimension and represent these regions as rectangles — then different parts of the electron's fuzzy position are contained in different parts of space. But surely this doesn't make sense. A position isn't the kind of thing that has parts. We can divide a *material* object and attribute a position to each of its parts, but we cannot divide a position and attribute a position to each part!

Hence space cannot be something that has intrinsic (in-built) parts, for if it were such a thing, the existence of its parts would imply that positions have parts. If we think of space as a 3-dimensional expanse, we must think of it as an *undivided* expanse. Paradoxically yet to the point, we may say that ultimately there is only one place, and this is everywhere.

Returning to our question about the two-slit experiment, is there an objective, physical difference between (i) "the electron went through L" and (ii) "the electron went through R"? Because space — considered as a self-existent ("substantial") expanse — is undivided, "parts of space" only exist in our imagination, and so do points, paths, and surfaces. The answer, therefore, is negative: there isn't any objective difference between (i) and (ii), unless something — some actual event or state of affairs — indicates which of the two possibilities actually took place. Otherwise the question "Through which slit did the electron go?" is meaningless. It then involves a false assumption, namely that the distinction we make between "going through L" and "going through R" corresponds to something in the actual, physical world.

If space (qua expanse) is intrinsically undivided, what gives rise to the spatial (or synchronic) multiplicity of the world? What makes "here" different from "there"?

To thinkers from Aristotle to Kant and Gauss it appeared self-evident that space wasn't composed of parts. They considered space an expanse that makes it possible to divide *material* objects. "Space is essentially one," Kant wrote, "the manifold in it ... arises entirely from the introduction of limits." Today physicists no longer reflect on space as a condition of perception and imagination, but they still hold (more or less implicitly) that spatial multiplicity rests on limits — bounding or dividing surfaces. This way of thinking — and perceiving — is inherent to mental (as against supramental) consciousness. It is one of its defining characteristics:

> 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 and employs them as fixed units of the material given to it for creation or possession. (Sri Aurobindo, 2005, pp. 173–174)

There is also considerable neuropsychological evidence that the brain processes sensory information in such a way that the result — the perceived world — is a world of objects whose shapes are first and foremost bounding surfaces (Mohrhoff, 2001, 2007). This appears to support the current view that the working of the mind is determined by the working of the brain, but let us keep in mind that, according to Sri Aurobindo (2005, p. 270),

> the physical sense-organs are not the creators of sense-perceptions, but themselves the creation, the instruments and here a necessary convenience of the cosmic sense; ...the brain is not the creator of thought, but itself the creation, the instrument and here a necessary convenience of the cosmic Mind.

Mind, however, is not the original creative principle. That, according to Sri Aurobindo, is the supermind. So we have no reason to expect that the synchronic multiplicity of the world rests on dividing or bounding surfaces. And in fact it doesn't. What our analysis of QM leads us to conclude is that spatial multiplicity rests on fuzzy relative positions. Consequently, the shapes of things are not boundaries but sets of fuzzy relative positions.

Remember the ancient conundrum about the divisibility of matter? If the synchronic multiplicity of the world rested on surfaces that carve up things much as cookie cutters carve up rolled-out pastry, then things ought to be divisible *ad infinitum*. If on the other hand we want to understand matter in the manner which has been paradigmatic for some 25 centuries — i.e., in terms of the composition and interaction of parts — then there have to be ultimate, not further divisible parts. But why then are these parts not further divisible? Thanks to QM, we know now why the modern "atoms" — quarks and leptons — are not further divisible. The reason they are not further divisible is that they are *formless*. The shapes of things resolve themselves into sets of fuzzy relative positions (or spatial relations) between formless objects.

If now you recall that ultimately there is only one "thing," and that this is or constitutes everything, you will conclude that the shapes of things resolve themselves into the *self-relations* of a single formless "something." Taking our cue from the Upanishads, we might as well call it Brahman. Brahman is said

- to be without form,
- to constitute all things,
- to contain all things,
- to originate all things.

Here is a nutshell account, based on QM, of how formless Brahman originates and comes to contain and constitute all things: *Brahman enters into spatial relations with itself.* As a result,

- there are things that have shapes (sets of spatial relations),
- there is space — Brahman as the one place that contains them all,
- there is matter — Brahman as the apparent multitude of relata ("apparent" because the relations are self-relations) and as the one thing that constitutes them all.

Can you think of a more concise creation story or a more economical way to manifest a world?

But why are the positions of Brahman relative to Brahman *fuzzy*? The answer is that this appears to be the only way to manifest "ordinary" objects. By this I mean objects that

- "occupy" space,
- are made of a large but finite number of objects that do not "occupy" space,
- are stable –they neither collapse nor explode as soon as they are formed.

The existence of such objects requires that the entire theoretical framework of contemporary physics has exactly the form that it does! If you want "ordinary" objects, you need QM. You also need Einstein's two theories of relativity as well as the rest of the Standard Model: electroweak theory and quantum chromodynamics, at least as effective theories (Mohrhoff, 2002, 2009).

Explanation: The general theory of relativity (Einstein's theory of gravity) and the so-called Standard Model (which is based on quantum theory and the special theory of relativity) comprise all well-tested physical theories. The electroweak theory is a unified theory of the electric force and the so-called "weak" nuclear force. Quantum chromodynamics is our theory of the so-called "strong" nuclear force. An effective theory is a theory that is valid on some but not all scales of length.

And you need *spin* — a property that has no classical analogue. It therefore can only be defined in quantum-probabilistic terms. Formally, it resembles a vector in that it has components. Measuring any spin component associated with any one of the "building blocks" of "ordinary" matter — a proton, a neutron, an electron, or a quark — yields either of two outcomes: +1 or −1 (in appropriate units). Moreover, it is impossible, on both theoretical and experimental grounds, to measure more than one component of the spin of any given particle at any given time.

Because of its small number of possible outcomes, experiments involving particle spins are ideal for demonstrating some of the common-sense-defying features of QM. For example, It is possible to prepare three particles A, B, C in a state that has the following properties:

- whenever the *x* components of their spins are measured, the product of the outcomes equals –1;
- whenever the *x* component of the spin of one particle and the *y* components of the spins of the two other particles are measured, the product of the outcomes equals +1.

Another million dollar question: is it possible for the spin components of the particles to have values even if they are not measured? If this *is* possible, then the following four equations hold:

$$X_A X_B X_C = -1 \qquad X_A Y_B Y_C = 1 \qquad Y_A X_B Y_C = 1 \qquad Y_A Y_B X_C = 1$$

Can they all hold with the same values of the spin components X_A, X_B, X_C, Y_A, Y_B, and Y_C?

To find out, let us multiply the last three equations (both the left-hand sides and the right-hand sides). This yields

$$X_A Y_B Y_C Y_A X_B Y_C Y_A Y_B X_C = 1$$

Since the Y factors appear twice, which is to say squared, and since their squares are equal to 1 (because their values are either –1 or +1), this boils down to $X_A X_B X_C = 1$. But this obviously cannot hold if the first equation $X_A X_B X_C = -1$ holds. Those four equations therefore cannot be satisfied by *any* given set of values X_A, X_B, X_C, Y_A, Y_B, Y_C.

And so it is *not* possible for the spin components to have values if they are not actually measured! Many other experimental arrangements lead to the same conclusion: for any physical property and any physical value, to *be* is to be *measured*.

This means that the values of the spin components are created as and when they are measured. Which raises another conundrum: on the basis of any two outcomes, the third outcome can be predicted. If, for instance, we measure the *x* components of particles A and B and thus know X_A and X_B, the equation $X_A X_B X_C = -1$ allows us to predict the outcome of a measurement of the *x* component of particle C. How is this possible, considering that the relative timing of the three measurements is irrelevant, and that in principle the three particles can be light years apart? How do the first two measurements influence the outcome of the third measurement? What kind of mechanism is at work? *You understand this as much as anybody else!*

The laws of QM are about correlations between measurement outcomes. The correlations are of two kinds: synchronic and diachronic. The former concern the outcomes of measurements that in some reference frames are simultaneous; the latter concern the outcomes of measurements that happen at different times regardless of the reference frame that is used to describe them. (Think of a reference frame as part of the physicist's language. As you can say the same thing in different languages, so you can describe the same experiment using different reference frames.)

Where the *synchronic* correlations are concerned, most physicists readily admit that they have no idea — in fact, cannot imagine — "how nature does it." One is therefore left to wonder how it is that there has been no dearth of attempts to explain the *diachronic* correlations.

One possible reason is this: we experience time as an ever-changing present. This suggests that we can describe the physical world by means of a time-dependent state: we thus have *kinematics*, which is concerned with the description (state) of a physical system at any one time, and we have *dynamics*, which is concerned with how a state changes with time ("evolves").

The advent of the special theory of relativity made it clear that this view was fundamentally flawed, for it implies that one can always pick three events A, B, C in such a way that

- A is objectively (i.e., regardless of the reference frame used) earlier than B,
- C is simultaneous with A if a certain class of reference frames is used,
- C is simultaneous with B if a different class of reference frames is used.

In other words, it is up to us how we conceptually decompose the four-dimensional "block" of space-time into three-dimensional "slices" containing simultaneous events. Only the "block" as a four-dimensional whole does not depend on the language we chose to describe the physical world. The physical description of the world is therefore at odds with our experience of time as an ever-changing present.

Tellingly, while physics here is again at odds with mental experience, it is once more in agreement with an aspect of supramental experience:

> The supramental consciousness … can either take its station in the time consciousness and keep the timeless infinite as its background of supreme and original being from which it receives all its organising knowledge, will and action, or it can, centred in its essential being, live in the timeless but live too in a manifestation in time which it feels and sees as infinite and as the same Infinite, and can bring out, sustain and develop in the one what it holds supernally in the other. Its time consciousness therefore will be different from that of the mental being, not swept helplessly on the stream of the moments and clutching at each moment as a stay and a swiftly disappearing standpoint, but founded first on its eternal identity beyond the changes of time, secondly on a simultaneous eternity of Time in which past, present and future exist together for ever in the self-knowledge and self-power of the Eternal, thirdly, in a total view of the three times as one movement singly and indivisibly seen even in their succession of stages, periods, cycles, last — and that only in the instrumental consciousness — in the step by step evolution of the moments. (Sri Aurobindo, 1999, p. 886)

Heedless of the lesson of special relativity, physicists have persisted in the "division of labor" between kinematics and dynamics. Specifically, they continue to think of quantum states as descriptions of physical systems that change with time. To understand their mistake, you need to recall that the mathematical formalism of QM is a collection of "computing machines." What you insert is a measurement to be made, the time of this measurement, and some relevant measurement outcomes previously obtained; what pops out is the probabilities of the possible outcomes of this measurement. The mistake is to transmogrify (i) this computing machine into an evolving physical state and (ii) the time of a measurement (which was to be inserted into the computing machine) into the time-dependence of this state. This sleight-of-hand has engendered a host of pseudo-problems and a whole industry dedicated to solving them. Chances are that if you pick a popular book on QM, it will regale you with some of these pseudo-problems and some of their (spurious) solutions. Meanwhile the question as to "how nature does it" has remained as elusive as ever.

To see why actually this should be so, look at it this way: in the quantum world everything is possible. To be precise: every conceivable measurement outcome has a probability greater than zero *unless* it violates a conservation law. Physics therefore *never* explains *how* something is possible, let alone "how nature does it." It only explains — via its conservation laws — why certain things *won't* happen.

But this is exactly what one would expect if the force at work in the world were an *omnipotent* force operating under self-imposed constraints. There would then be no reason to be surprised by the apparent impossibility of explaining the quantum-mechanical correlations laws — to account for them in terms of mechanisms or processes — for it would be self-contradictory to explain the working of an omnipotent force. What needs to be explained is why this force works under self-imposed constraints, and why under this particular set of constraints.

As we have seen, the purpose of this particular set of constraints is to allow for the existence of stable objects that "occupy space" even though they are made of finite numbers of objects that do not "occupy space."

But why are objects that "occupy space" made of finite numbers of objects that do not "occupy space"? One possible answer is, to set the stage for the adventure of evolution. According to Sri Aurobindo, evolution presupposes involution, and the final outcome of the process of involution is the creation of a universe in which objects that "occupy space" are made of a finite number of formless objects and obey the well-established physical laws, at least initially. We shall look into this process in the next lecture.

Right now, another mystery calls for attention. As indicated earlier, physical properties — the values of physical quantities — are possessed only if, only when, and only to the extent that they are measured (that is, indicated by or inferable from an actual event or state of affairs). Why? Because a macroscopic apparatus is needed to realize (make real) attributable properties. A detector, for instance, not only serves to indicate the presence of something in its sensitive region *R* but also, and in the first place, to realize the property of being in *R*, to make it available for attribution. By the same token, an apparatus for measuring the spin of a particle is needed not only to indicate an outcome but, in the first place, to realizes the axis with respect to which the spin is measured. (This is the experimental reason why the spin components of a particle can be measured only one at a time.)

It follows that the so-called microworld is what it is because of what happens or is the case in the macroworld, rather than the other way around, as we are wont to think. This too runs counter to the twenty-five year old paradigm which asks: what are the ultimate building blocks, and how do they interact and combine? The right question to ask is: how does Brahman manifest the world — or manifest itself *as* the world? It is no longer appropriate to model physical reality "from the bottom up," by assembling pre-existent building blocks, or by constructing a model of reality on the foundation of an intrinsically differentiated space or space-time. Molecules, atoms, and subatomic particles are instrumental in the manifestation of the macroworld, rather than being its constituent parts or structures, or forming an "underlying" microworld. QM affords us a glimpse "behind" the manifested world, at what is instrumental in its manifestation, but it does not let us describe what we see except in terms of the finished product — the manifested world.

If we conceptually partition the world into smaller and smaller regions, we reach a point at which the distinctions we make between regions no longer correspond to anything in the actual world. And if we keep dividing a material object, its so-called "constituents" lose both their form and their individuality. We reach an omnipresent point and an all-constituting substance. If we follow the opposite direction, starting at formless Brahman, we obtain insight into the coming into being of form. Begin by adding self-relations to this all-constituting substance, which owe their quality of spatial extension to that omnipresent point. This yields composite objects such as protons and atoms. These objects cannot be visualized "as they are." They can only be described abstractly, in terms of correlations between measurement outcomes. The smallest objects with an aspect that can be visualized "as it is" are molecules. This aspect corresponds to the sticks in the chemist's balls-and-sticks model of a molecule. Forms thus arise by a self-differentiation of Brahman that results in a multitude of fuzzy spatial relations, which serve to manifest the shapes of things. As it was said in the Rig Veda, the foundation is above.

The self-differentiation of Brahman, moreover, does not go "all the way down" since beyond a certain point we return to the undifferentiated unity both of space and of substance. Nor could it go all the way down, for if it did, the spatial relations between Brahman and Brahman could not be fuzzy, and ordinary objects as previously defined could not exist.

The creations of the supermind — the conscious force by which Brahman qua substance takes on forms and Brahman qua consciousness give itself content — are primarily qualitative and infinite, and only secondarily quantitative and finite. Essentially, mind is the agent of the supermind's secondary, limiting and dividing action. When Mind is used by Supermind, its tendency to divide *ad infinitum* is checked. This is why the self-differentiation of Brahman does not go "all the way down," and why it is impossible to construct reality from the bottom up. When mind is separated in self-awareness from its supramental parent, 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 why we keep trying, unsuccessfully, to construct reality from the bottom up.

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