Finding Wisdom in Contemporary Physics

Ulrich Mohrhoff
Sri Aurobindo International Centre of Education
Pondicherry, India

Theosophy Science Lecture delivered at the 138th Annual International Convention of the Theosophical Society, December 29, 2013.

Synopsis

Quantum mechanics is the general theoretical framework of contemporary physics. While its stunningly elegant mathematical formalism can be written down on a napkin, attempts to make sense of it fill entire libraries. Not once has a reliable experiment or observation been at odds with its predictions. Its ever-growing range of technological applications borders on magic, yet no one seems to know how the magic works. Subatomic particles, atoms, and even molecules behave in ways which are quite unlike what we know how to think about.

The reason this is so is that quantum mechanics does not explain how the world is put together. What it is trying to make us understand is how the world is *manifested* — how a single nameless Reality becomes many without ceasing to be the "One without a second" of the Upanishads. Instead of being interacting constituents of matter, subatomic particles, atoms, and molecules are instrumental in the manifestation of the material world. They are stages in the transition from the One to the Many. While the familiar explanatory categories of substance and causality allow us to make sense of the manifested world, they are useless when it comes understanding how the world is manifested. They belong to the rules of this *Lila* but have no part in setting the stage for it.

Yet it is possible to understand why the well-tested laws of physics have the form that they do. For this we need to know what this *Lila* is about. Sri Aurobindo tells us that our world is special in that it is evolutionary. Evolutions presupposes involution: the involution of Supermind in Mind, the involution of Mind in Life, and the involution of Life in Matter. When Life — the force that creates and sustains forms — is involved in Matter, the result is a multitude of formless entities, which are none other than the elementary particles of particle physics.

Once it is granted that the purpose of this manifestation is the evolution of Life, Mind, and eventually Supermind, and also that this evolution begins with a multitude of formless particles, we are in a position to understand why the general theoretical framework of physics has to be quantum mechanics. Life and Mind cannot possibly evolve if there are no stable objects of finite size, and the existence of such objects requires the validity of quantum mechanics. If, moreover, we take into account that the evolution of Life requires habitable environments in which a sufficient variety of chemical elements is available, we find that every one of the well-tested laws of physics is necessary for the purpose of this manifestation.

On the face of it, all that quantum mechanics allows us to calculate is correlations between measurement outcomes. The fact that these correlations cannot be understood in causal terms has aroused much consternation. No physical mechanism, no natural process is able to explain them. Yet if the force at work in the world is an *infinite* force, this should be no cause for concern, for it would be self-contradictory to explain the working of an infinite force in terms of physical mechanisms or natural processes. If this force works under self-imposed constraints, we need to know why it does so, and why the self-imposed constraints have the form that they do. And this we now know. The laws of physics are what they are because they are needed to set the stage for this *Lila* of evolution.

I shall begin with a problem that Scholastic philosophers have discussed for centuries. Imagine that you have in front of you two exactly similar objects. They are completely identical, all their properties are the same, except that they are in different places. Because they are in different places, they are different objects. The problem is this: Is the fact that they are in different places the *sole* reason why they are different objects? Or is there another reason?

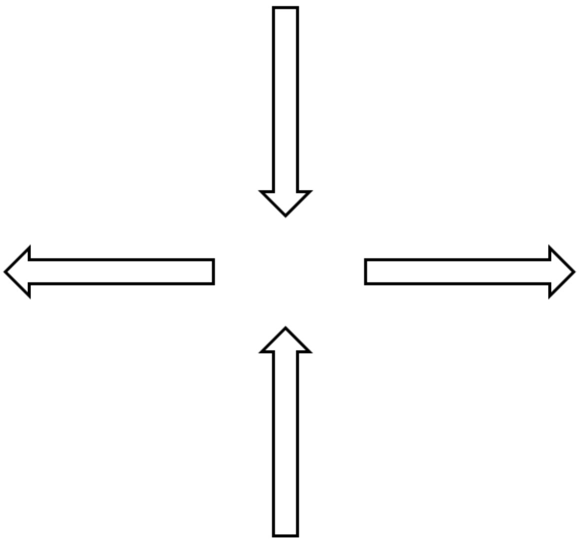
If you believe that there is another reason, you will look for it in vain, for if two objects are different, it is their properties that are different, and right now we are assuming that the two objects have exactly the same properties, except that they are in different places.

On the other hand, if you believe that the two objects in front of you are different objects for the *sole* reason that they are in different places, then what you really believe is that the two objects in front of you are the *same* object in two different places, which seems preposterous.

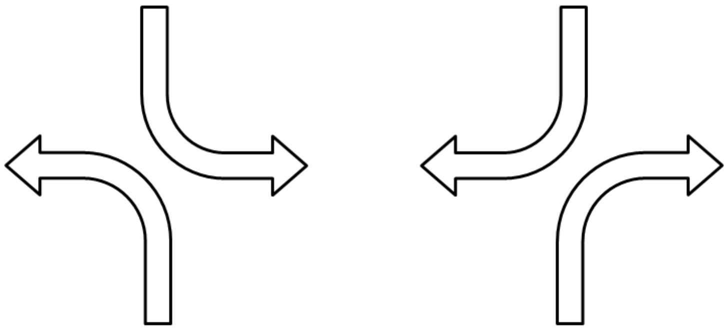
The resolution of this dilemma had to wait for the advent of quantum mechanics.

Quantum mechanics has been called "a wolf in sheep's clothing" [1]. While its stunningly elegant mathematical formalism can be written down on a napkin, attempts to make sense of it fill entire libraries. Not once has a reliable experiment or observation been at odds with what it predicts. Its ever-growing range of technological applications borders on magic, yet no one seems to know how the magic works.

One reason why quantum theory has such mindboggling implications is that it has not one but two general rules for calculating probabilities. Imagine two elementary particles that are heading towards each other. One is moving northward, the other is moving southward. We want to calculate the probability with which the two particles scatter each other at right angles, so that one ends up moving eastward and the other ends up moving westward:



The first of those two rules must be used if what really happens corresponds to either the left or the right diagram:



You may wonder how it can be otherwise. Is there any other way for a northbound and a southbound particle to turn into an eastbound and a westbound particle? Apparently there is, for if it is impossible to know in which of the two ways the scattering takes place, we must use the second rule.

Now it could be that even if we cannot *know* which way the scattering takes place, it may still be that it takes place in one or the other of these two ways. But no! If one or the other takes place, we must use the first rule, and if we cannot know which of the two takes place, we must use the second rule.

But are there situations in which it is impossible to know this? Such a situation occurs if the incoming and outgoing particles are of the same type, say: two electrons in, two electrons out. In this case there is no answer to the question “Which incoming particle is identical with which outgoing particle?”

Quantum mechanics thus tells us in no uncertain terms that some very sensible questions about what happens in the world *cannot* be answered. And since questions that cannot be answered usually arise from false assumptions, it tells us that something we take for granted is actually false. So what do we take for granted when we ask “Which incoming particle is identical with which outgoing particle?”

It is this: we assume that initially there are *two* things, one moving southward and another moving northward, and that in the end there are again *two* things, one moving eastward and another moving westward. To avoid asking the unanswerable question, we ought not to assume that we are dealing with two things. Instead we should assume that initially there is but *one* thing that moves *both* northward and southward, and that in the end there is the same *one* thing that moves *both* eastward and westward. If there is but one thing, the question “Which is which?” obviously cannot be asked.

This is how quantum mechanics resolves the dilemma of the Scholastic philosophers. The two objects they contemplated *are* the same object in two different places. Reality *is* preposterous.

The conclusion that the two particles are one and the same thing in different places, or one and the same thing moving in different directions, also holds if the two particles are not of the same type. What can simultaneously have different positions, or move in different directions, can also simultaneously possess different properties other than position or direction of motion. To my mind, this is the most significant conclusion that can be drawn from the general theoretical framework of contemporary physics: ultimately there is but one thing, and this one thing is everything. To be precise: it is every one of the elementary particles of which matter is said to be composed, without ceasing to be one and the same thing.

But let me be frank: while this conclusion can be drawn — and I want you to know that it can be drawn — it is not a conclusion that a significant number of physicists would endorse. I am sure you can see why. Here is how the philosopher of science Dennis Dieks [2] describes the situation:

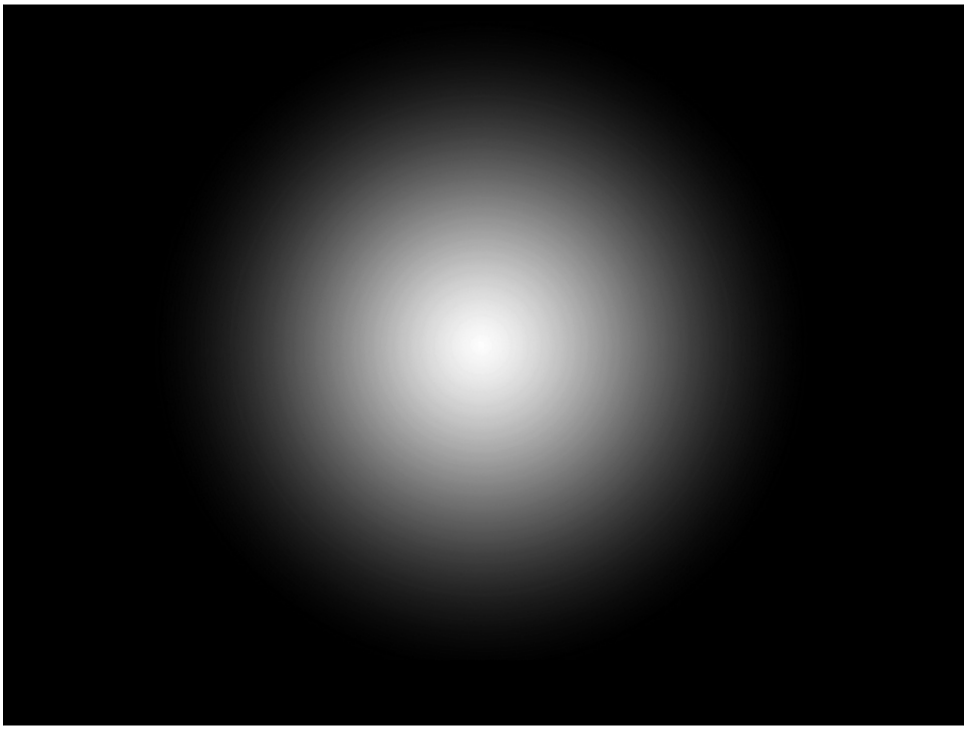
> Most physicists have no clear conception of the interpretation of their most basic theory, quantum mechanics. They are largely unaware of the exact nature of the problems in giving a detailed and consistent account of the physical meaning of the theory; and if they are aware, they often don't care very much. Only very small numbers of researchers have given serious thought to the interpretational problems of quantum mechanics, and have expressed more or less detailed points of view. As can perhaps be expected from the statistics of small numbers, the diversity of opinion is large. Very different ideas have been put forward, none of them supported by great numbers of physicists.

This situation is exacerbated by the fact that instead of addressing genuine philosophical issues, much effort is directed at solving spurious problems. The following are two of the genuine problems:

1. Why is the general theoretical framework of contemporary physics a tool for assigning probabilities to the possible outcomes of measurements?
2. Why does the concept of "measurement" play an essential role in the formulation of a fundamental physical theory?

We can answer these questions by asking how it is that "ordinary" objects exist. An "ordinary" object occupies a finite volume of space. It is (or appears to be) "made of" a large number of particles, none of which occupies any space. And it is reasonably stable. The crucial insight, which led to the discovery of quantum mechanics, was that an ordinary object cannot be stable unless the positions of its constituent parts are fuzzy.

What do I mean by a fuzzy position? Take a look at this 3-dimensional, spherical "cloud":



It depicts the fuzzy position of the electron (relative to the nucleus) in a hydrogen atom in its state of lowest energy. Intuitively it seems clear enough that the fuzziness of this position can be responsible for the atom's size. But how does one describe a fuzzy position mathematically? One describes it by assigning *probabilities* to the possible outcomes of a position *measurement*. The probability of finding the electron is highest at the centre, where the nucleus is situated, and decreases with distance from the centre.

The fuzziness of the positions of particles and of other physical quantities is the reason why the general theoretical framework of contemporary physics is a calculus of probabilities, and why the concept of "measurement" plays an essential role in the formulation of the theory.

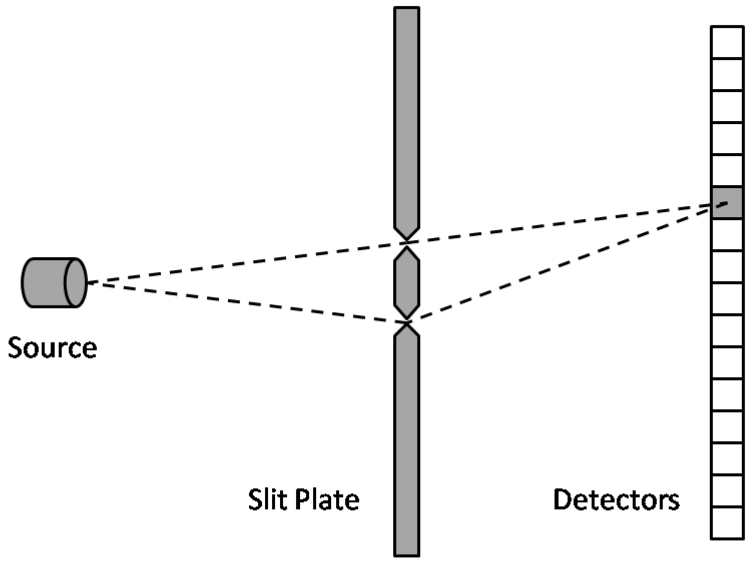
The following, by contrast, is a spurious problem: How is it that measurements have outcomes?

Isn't this an odd question to worry about? Everyone knows that measurements have outcomes. Even funding agencies and science advisors to governments are convinced, otherwise they would not have sanctioned the 10 billion Dollars it cost to build the machine that discovered the Higgs boson. How is it that so much effort has been and still is being spent on explaining how measurements come to have outcomes?

Theoretical physicists like to think of the formalism of a physical theory as if it were a mathematical description of a part or an aspect of the world. Quantum mechanics, however, only provides us with tools for calculating the probabilities of measurement outcomes. It is not a mathematical description of any part or aspect of the world. That spurious problem arises because a tool for calculating the probabilities of measurement outcomes is being treated as if it were the mathematical description of an actual part or aspect of the world. If this happens, one ends up treating *every possible* outcome as if it were an *actual* outcome. And if one does that, one has to explain how it is that whenever we make a measurement, we obtain a single outcome instead of every possible outcome. The mathematician John von Neumann, who was the first to formulate this spurious problem, concluded that this single outcome exists only in the mind of an observer.

Some of you will have read, and may even have come to believe, that quantum physics requires the existence of observers. If von Neumann was the first to jump to this erroneous conclusion, Fritjof Capra was the first to popularize it in his bestseller *The Tao of Physics* [3]. Capra supports this conclusion by confounding two issues. One issue concerns the *mind*-independent existence of the world, the other concerns its *measurement*-independent existence. I am happy to say that quantum mechanics allows you to think that the Moon is there even if nobody looks at it. What calls for explanation is not why the properties of an atom cannot be defined without reference to conscious observers — they can — but why they cannot be defined without reference to *experiments*.

So why is it not possible to define the properties of an atom independently of measurements? The following setup can help to explain this:



There is a plate containing two slits, a source of electrons in front of the plate, and an array of detectors behind the plate. If we want to calculate the probability with which an electron will be detected by a particular detector, we are again confronted with the curious fact that quantum mechanics has two general rules for calculating probabilities. Here we must use the first rule if the electron goes through either the left slit or the right slit.

Again you may wonder how it can be otherwise. Is there a third way for an electron to pass the slit plate? Apparently there is, for if it is impossible to know through which slit the electron goes, we must use the second rule. In this case the electron goes through both slits without going through a particular slit and without being divided into parts that go through different slits. How can that be?

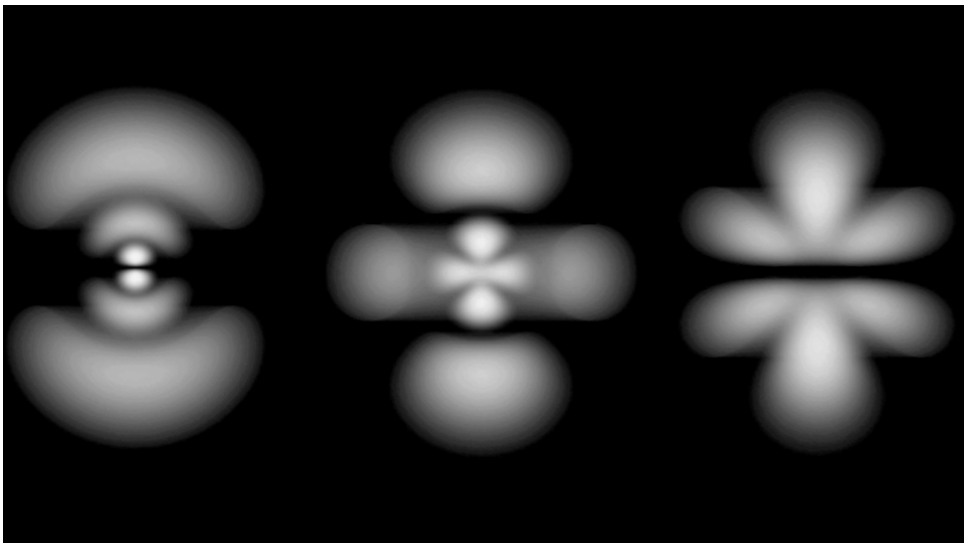
Once again quantum mechanics tells us that a distinction *we* make is a distinction that Nature does not make. We speak of “regions of space” as if space itself had parts that are distinct from each other. We tend to think that the two slits are objectively distinct regions of space, and that therefore nothing can pass the slit plate without going through a particular slit *and* without being divided into parts that go through different slits. Hence our consternation at being told by Nature, through quantum mechanics, that this is precisely what subatomic particles, atoms, and even molecules can do. What Nature is thereby trying to tell us is that space is not something that has parts. Just as quantum mechanics tries to make us understand that ultimately there is but one thing, and that this one thing is everything, so it is trying to make us understand that ultimately there is only one place, and that this one place is everywhere.

What furnishes space with its so-called parts is its material content. What makes it possible to attribute to a particle or an atom the property of being in a particular "region of space" is a detector. By being a property of a macroscopic detector, the region monitored by the detector becomes a property that can be attributed to a microscopic object. The property of being inside this region becomes a property of a particle if the detector "clicks," that is, if it indicates the particle's presence in its sensitive region. If a region is not monitored by a detector, the property of being inside that region cannot become the property of a particle. This illustrates why the properties of a particle or an atom cannot be defined without reference to experimental arrangements, such as an array of detectors.

Just now I made the distinction between macroscopic objects and microscopic ones. What exactly sets macroscopic objects apart? As you will remember, one reason why "ordinary" objects can exist is that the positions of their constituent particles are fuzzy. What distinguishes macroscopic objects from microscopic ones is that the fuzziness of *their* positions is not an objective feature of the physical world. This is why the positions of macroscopic objects are the exception that proves the following rule: *the properties of physical objects exist only if and only when they are measured*.

But now we seem to be confronted with a vicious logical circle. On one hand, macroscopic objects are made of atoms, which are made of subatomic particles. On the other hand, the properties of atoms and subatomic particles exist only if and only when their existence is indicated by macroscopic objects. How can macroscopic objects be made of objects whose properties only exist when they are indicated by macroscopic objects?

The following example may help to explain this.



Each of these “clouds” represents the fuzzy position of the electron relative to the proton in a particular state of a hydrogen atom. Each state is determined *by* measurement outcomes, and in turn it determines the probabilities *of* measurement outcomes. Each cloud is determined by the outcomes of three measurements: a measurement of the atom’s energy, a measurement of its total angular momentum, and a measurement of the vertical component of its angular momentum. And each cloud determines the probabilities of the possible outcomes of a position measurement: where the density of a cloud is greater, the probability of finding the electron is higher. In short, the description of an atomic system is a description in terms of *correlations between measurement outcomes*.

The reason why no logical circle occurs is that we can understand atomic systems in terms of correlations between the outcomes of measurements *that are not actually made*. Such a description does not involve properties that are possessed by atomic systems. We can understand the role that a microscopic object plays in the manifestation of a macroscopic object without attributing to it properties that only exist when they are measured by macroscopic objects.

If you are flummoxed by all this, join the club. Microscopic objects are *bound* to behave in unfamiliar ways, for if they are to explain the properties and the behaviour of macroscopic objects, they *cannot* have the same properties or behave in the same way as macroscopic objects. If they did, nothing would have been explained.

The quantum-mechanical correlations between measurement outcomes are a major offence to common sense. For an example, imagine a diatomic molecule that dissociates into its constituent atoms, which fly off in opposite directions. The atoms have a property called spin. This can be measured with respect to any axis, which is determined by the orientation of the measurement apparatus. Whenever the spins of the two atoms are measured with respect to the same axis, we find that they point in opposite directions. How can we understand these correlations?

Understanding correlations is a tricky business, as the following scenario will illustrate. A large ice cream company in the USA had recorded its sales over a period of several years.

When this record was compared with a record of drowning incidents during the same period, it was found that whenever the ice cream sales were higher, more people drowned. There are three ways to understand this correlation. Either more people drowned because more ice cream was consumed, or more ice cream was consumed because more people drowned, or there was something else that caused the correlation between the consumption of ice cream and the number of drowning incidents. In this example the correct answer is obvious. There was something else that caused the correlation, namely the weather. On warmer days more ice cream was consumed, more people went swimming, and therefore more people drowned.

Suppose now that the spins of the two atoms have been measured with respect to the same axis, and that the outcomes are *up* for the first spin and *down* for the second. We again have three possible explanations. (1) The first outcome is *up* because the second outcome is *down*. (2) The second outcome is *down* because the first outcome is *up*. (3) Something else causes the two outcomes to point in opposite directions. The trouble is that none of the three explanations work. Beginning with the celebrated proof by John Bell [4] in 1964, an ever-growing number of theorems show that these correlations do not admit of explanations in terms of cause and effect.

For most physicists the ultimate goal of physics is to discover the ultimate building blocks of the universe and the forces by which they affect each other. What has actually been discovered, however, is that the search for building blocks was misconceived. Quantum mechanics does not permit us to model reality "from the bottom up" — either out of a multitude of building blocks or by assigning properties to the points of space. Every one of the particles of which matter is said to be made, turns out to be one and the same thing, and just as there are no "parts of space," so there are no "points of space."

Quantum mechanics does not explain how the world is put together. What it is trying to make us understand is how the world is *manifested* — how a single nameless Reality becomes many without ceasing to be "One without a second," *ekamevādvitīyam*.

We can see this more clearly if instead of asking what *things* are made of, we ask what *forms* are made of. Elementary particles like electrons are formless. While physicists often speak of them as pointlike, this only means that they lack internal structure. The shapes of things are made of the spatial relations — the relative positions — between formless particles. Because each particle is the "One without a second," these relations are reflexive. The shapes of things are made of self-relations — relations between the One and Itself.

Quantum-mechanically conceived, the form of a material object is a probability distribution over a multidimensional probability space. This is a highly abstract concept, which cannot be visualized. Forms that can be visualized — concrete shapes in three-dimensional space — only emerge at the molecular level of complexity, as atomic configurations of larger molecules.

Atoms and subatomic particles, therefore, should not be thought of as constituent parts in the sense of being distinct objects with separate and independently existing properties, acting on each other according to laws of cause and effect. They are tools by which the "One without a second" manifests a multitude of macroscopic objects. They are instrumental in the process of manifestation. Only macroscopic objects can be treated as distinct objects with separate and independently existing properties, which act on each other according to laws of cause and effect. The categories of substance and causality, therefore, which allow us to break down things into interacting bundles of properties, are useful only within the manifested world. When we try to apply these categories to the process of manifestation rather than to its result, they lead us astray. They belong to the rules of this *Lila* but have no part in setting the stage for it.

So what is this *Lila* about, and what else does it take to set the stage for it? According to the original Vedanta of the Upanishads, the world is a manifestation of some Ultimate Reality. As *Sat* or substance it constitutes the world, as *Chit* or consciousness it contains the world, and as *Ānanda* or delight of existence it expresses and experiences itself in the world. According to Sri Aurobindo [5], the process of manifestation involves four additional principles: Supermind, Mind, Life, and Matter. While Supermind encompasses the entire process, its creations are primarily qualitative and infinite. Mind is the agent of Supermind's secondary action, an action that is quantitative and finite, that creates limits and divisions. Life is the force that executes what mind conceives, and Matter is the result.

To this Sri Aurobindo adds that the particular manifestation in which we participate is special in that it is evolutionary. Evolution presupposes involution — the involution of Supermind in Mind, the involution of Mind in Life, the involution of Life in Matter. A supramentally conscious being knows itself to be the "One without a second." When Supermind is involved in Mind, we have a world of conscious beings who have lost sight of their mutual identity. When Mind is involved in Life, the force of Life receives the ideas it serves to execute from a subliminal source. And when Life — the force that creates and sustains forms — is involved in Matter, the result is a multitude of formless entities, which are none other than the "elementary particles" of particle physics.

Once we know that the purpose of this manifestation is the evolution of Life, Mind, and eventually Supermind, and also that this evolution begins with a multitude of formless particles, we are in a position to understand why the general theoretical framework of physics has to be quantum mechanics. Life and Mind cannot possibly evolve if there are no stable objects of finite size, and the existence of such objects requires the validity of quantum mechanics. If, moreover, we take into account that the evolution of Life requires habitable environments in which a sufficient variety of chemical elements is available, we find that every one of the well-tested laws of physics is necessary for the purpose of this manifestation.

I mentioned that quantum mechanics does not admit of explanations in terms of cause and effect. There is no physical mechanism, no natural process, that could explain the quantum-mechanical correlations between measurement outcomes. This has aroused much consternation. Yet if the force at work in the world is an *infinite* force, it should be no cause for concern, for it would be self-contradictory to explain the working of an infinite force in terms of physical mechanisms or natural processes. If this force works under self-imposed constraints, what we need to know is why it does so, and why the self-imposed constraints have the form that they do. And this we now know. The laws of physics are what they are because they are needed to set the stage for this *Lila* of evolution.

1. M. Schlosshauer, *Elegance and Enigma*, Springer, 2011, p. 19

2. D. Dieks, “The Quantum Mechanical Worldpicture and Its Popularization”, *Communication & Cognition* 29 (2), 1996, pp. 153–168

3. F. Capra, *The Tao of Physics*, Shambhala Publications, 1975

4. J.S. Bell, “On the Einstein Podolsky Rosen paradox”, *Physics* 1, 1964, pp. 195–200

5. Sri Aurobindo, *The Life Divine*, Sri Aurobindo Ashram Publication Department, 2005