# ‘*Reality*’ *in modern physics*

## The Copenhagen interpretation

According to modern physics, the world is made up from small bits of energy, called ‘quanta’. Each object in the world is a quantum system, made up of individual quanta acting together. In effect, this is like saying that the world and its objects are made up of interacting particles, except that quanta are not quite particles.

The trouble is that quanta sometimes behave like particles, and they sometimes behave like waves. Broadly speaking, when we consider a quantum system evolving on its own, we describe its behaviour as though it were a system of waves. But, if we consider a quantum system interacting with something else, the interaction is described as though the quantum system were made up of uncertain particles.

For example, if we consider a beam of light, it travels through space as though it were made up from waves. It gets bent or ‘refracted’ when it passes through regions of space where its speed changes; and this refraction gives rise to the colours of the rainbow, as different wavelengths of light get differently bent.

But, if the same beam of light strikes the surface of a photo-electric metal, this light now behaves like a stream of particles, which strike against orbiting electrons in the metal atoms. Some electrons are thus knocked out of orbit, right out of the metal surface. The results are a build-up of electrical charge and a flow of electric current.

This dual nature of quanta (acting sometimes like particles, sometimes like waves) has some strange implications. As a further example, suppose that a screen with two neighbouring slits is placed in between a source of light and a photographic plate. An illustration is given in figure 1 (overleaf).

Next, suppose that just one quantum of light travels from the source, through the slits, to the photographic plate. This single quantum of light, which is called a ‘photon’, travels like a wave. From its source, the wave

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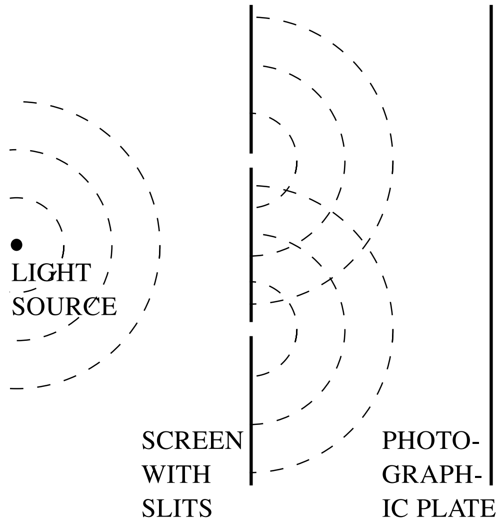
*Figure 1*



motion does not travel to only one slit, but to both. At each of the slits, an onward wave motion is produced, on the other side of the screen. From the screen, the wave motion thus proceeds split up into two onward wave motions, which interfere with each other so as to produce a 'diffraction' pattern of high and low intensity bands on the photographic plate (high where the split-up wave motions reinforce each other and low where they cancel each other out).

However, when the photon (or quantum of light) interacts with the photographic plate, it interacts as a particle. So it has an effect at just one particular place, and it shows up as only a single spot of light. Later on, if another photon is released in the same way from the source of light, a single spot of light again shows up on the plate; but this second spot is liable to be in a different place. If photons keep being released like this, over and over again, there will be many spots on the screen. And gradually, as the number of spots increases, they will build up a pattern of light and dark bands, corresponding to the diffraction pattern of high and low intensity that is caused by each photon's wave motion.

What the wave motion does is to somehow represent a tendency for each photon of light to appear at particular places on the photographic plate, after its release from the source of light. Where the intensity of the wave is high, the tendency for a photon to appear is high. Where the intensity is low, so is the tendency for a photon to appear there.

But what exactly is this wave motion that somehow describes such tendencies of appearance? In the Copenhagen interpretation of quantum physics (which is generally accepted by most physicists today), the wave motion is simply a transmission of probability. Instead of a piece of matter travelling through space and time, there are only evolving probabilities: of where the matter might be located, how fast it might be travelling, what its size or shape or energy might be, and so on. Instead of a 'classical' equation in which a measurable variable (like distance, time, speed or energy) has a definite value, there is a wave equation in which each measurable variable is represented by a spread-out function, calculating a probability distribution for many possible results that may occur when the variable is measured.

But a further question arises. What is being measured here? Or in other words, what reality is represented by the measurable variables of quantum physics?

The Copenhagen interpretation does not positively answer this question, about the ‘reality’ of what is measured. Instead, it takes a negative approach: by pointing out the inadequacy of our conventional ideas about a material reality, made up of definite objects located within definite boundaries in space and time. And it modifies our conventional ideas, by adding three principles:

- A principle of *discontinuity*, that energy occurs in discontinuous bits called ‘quanta’.
- A principle of *complementarity*, that quanta sometimes appear as particles and sometimes as waves.
- A principle of *uncertainty*, that our observations have always a minimum uncertainty built into them, as stipulated by Heisenberg’s equation.

When these three principles are added to our conventional ideas of the world, the result is a hybrid picture. In it, we still think of material particles and objects; but they are not quite the particles and objects that we usually think of, because they have no definite location or speed or momentum or energy. Though our instruments interact with them and measure them as uncertain particles and objects, when left alone they travel and evolve as patterns of waves. And here too, these waves are not quite the waves that we usually think of; because their energy is mysteriously forced to occur in discontinuous quanta, instead of the continuous energy flow that is natural to our usual ideas of wave motion.

This hybrid picture is paradoxical and complicated, but it has been very useful: in calculating results and developing technology. Does this mean that there is no further reality, beneath the paradoxical and complicated descriptions of our currently useful and widely accepted quantum picture?

History would suggest otherwise. Newtonian physics was similarly useful and widely accepted; yet Einstein and other modern physicists have looked beneath its paradoxes so as to produce relativity and quantum theories, which show that ‘reality’ is rather different from what superficially appears in the Newtonian picture.

And, to go further back, Newtonian physics resulted from a previous questioning of the Ptolemaic picture that the earth is the centre of the universe, around which the planets and stars revolve. In its day, the Ptolemaic picture was widely accepted, and through the complications of its epicycles it was technically very successful. But, by looking for a simpler and more consistent reality beneath these complications, Copernicus showed that it makes more sense to look at the earth as revolving about the sun. Newtonian physics was later made possible by this simplifying change of view that Copernicus's questioning brought about.

Similarly, it might perhaps be useful to try looking beneath the complications and paradoxes of quantum theory, for some simpler and more consistent view of an underlying reality. The one thing quantum theory does is to throw our usual ideas of 'reality' into question. So much so that modern physicists are often tempted to give up altogether on the concept of 'reality'. However, before doing that, it may be worth asking what the concept means, not just in the science of physics but in our broader experience as well.

### Appearances and reality

Suppose that we examine a table, to find out what it really is. If we look from above, we see a flat table-top. If we look beneath, we see four legs supporting the top. From different angles of vision we see different visual pictures, of the top joined with its supporting legs. From closer up, we examine the joints and infer their construction; or we inspect the surface, feel its texture and rap our knuckles on it, to learn about the material of which the table is made.

In each perception of the table, there arises an appearance: be it a visual picture of a flat top and four legs, or a mental picture of how the joints are constructed, or a sight or feeling of texture, or a sound of rapping knuckles, or a sudden feeling of hard impact. These perceived appearances are different from one another, but they each tell us something about the table. They are different appearances of the same thing, which we call the 'reality' of the table.

This is what's meant by the word 'reality'. It is that which stays the same, no matter how differently it may appear when perceived in different ways. If a change of view makes something change, then that changing something is not real. Instead, it must be an appearance: like the changing picture of a table that is seen from different angles of vision.

In short, the test of reality is its invariance, through the variation of appearances. When we search for reality, we are looking for invariant principles, which are shared in common by differing appearances. As more and more appearances arise, they tell us more and more about reality; and we take them into account by identifying deeper principles that are invariant through broader experience. Thus we come down to deeper levels of appearance, where we identify deeper principles that remain invariant through their varying appearances at more superficial levels. And in turn, such deeper principles may turn out to be varying appearances of a smaller number of even deeper principles that they manifest in common.

For example, though a table appears very differently through our different senses and from different points of perception, we are able to identify it as a three dimensional piece of matter, which its varying appearances show in common. If it is seen by different people, of differing personal and cultural backgrounds, they may call it by different names and have very different ideas about it; but their physical senses are similarly constructed, and through these similar senses they would normally arrive at a common identification of it: as a smooth and solid piece of matter with a well-defined boundary. So we usually take it for granted that this sensual identification is real, beneath the differing perceptions and descriptions and ideas through which the table appears to us.

However, modern science tells us otherwise. When the table is viewed under a microscope, previously unseen irregularities and holes appear in it; showing that the table is not smooth and solid, as it appears to our unaided senses. When the microscope's view is taken into account, the smoothness and solidity are shown not to be invariant; and so they cannot be real, but are only sensual appearances.

Looking more closely, at greater magnification, the table turns out to be made of molecules and atoms, vibrating in a way that our eyes do not see, but our skin feels as temperature. What previously appeared to be a fixed and solid piece of matter now turns out to be made of moving particles with quite a bit of empty space in between.

And if we look even more closely, at what happens inside atoms, then we come to the level of quantum physics: where the table is seen to be made of quanta, which sometimes appear to behave like particles and sometimes appear to behave like waves. In the Copenhagen interpretation, this conflict of appearance is left unresolved. Instead of looking for a common principle that underlies the particle and wave appearances of quanta, the Copenhagen interpretation uses ideas of uncertainty and probability to juxtapose these two conflicting appearances, without giving up either of them.

This conflicting juxtaposition creates a host of conceptual difficulties and paradoxes, because it goes against the very basis on which science is built. In effect, the Copenhagen interpretation makes science shoot itself in the foot. For science is and has always been based upon the search for an invariant and certain reality, beneath the variations and uncertainties of appearance.

But is there any concept in physics which might lead beyond the Copenhagen interpretation, by describing a common principle that could manifest both the particle and the wave appearances of quanta? Yes there is such a concept; and it is prominently used in quantum theory. It is the concept of 'field'.

## Field

In our usual way of looking at the world, we think of matter as real and we consider space, time and energy as properties or attributes of matter. We think of space as the distance that separates material objects, of time as the duration that separates material events, and of energy as the forcible work through which one object acts upon another.

In modern physics, the concept of 'field' turns attention from matter to space. And in this concept, space is no longer seen merely as a separating distance. Instead, it is considered as a continuity: which joins together the events of space and time. This continuity is called the 'space-time continuum', or just 'space-time' for short. It is a continuing environment of space and time in which each object and event appears. As objects and events appear, the space-time continuum manifests its own 'field' properties, which condition each of its localities. Mathematically such a field is described by attributing a mathematical value (like a number, or set of numbers) to each point of space and time.

This conceptual transition, from matter to field, has a simple, but far-reaching aim. It is to describe objects and events as manifestations of an underlying field that continues through them. We would then no longer need to conceive objects as separate pieces of matter, which interact through force. Instead, we could consider separated matter and its differentiated properties as manifestations of an underlying field that continues through their apparent separations and differences.

Such a conceptual transition has not so far been effectively achieved. The trouble is that our current conceptions of field are still mainly hybrid. They are still mixed up with the very concept of matter that a more profound field description should ideally explain.

For example, consider a climatic field of temperature, humidity and wind. Here space is conditioned by the values of temperature, humidity and wind velocity that occur at each point. But temperature, humidity and wind are properties of matter, not of space-time itself. Temperature is a property of random particle movement; humidity is a property of water vapour content; and wind is a property of aggregate particle movement. So this climatic field description is largely based on the concept of matter.

Next, consider a field of force, like electromagnetism or gravity. In such a field, space is a medium through which force is transmitted from one object to another. One object affects its surrounding space, so as to create a field. And this field affects another object, by exerting a force on it. Here the field is not just a material property, but a property of space; for the force can be transmitted through empty space, without any matter in it. As for example, electrically charged objects can attract or repel each other through the empty space in a vacuum tube, or the sun attracts the earth across millions of miles of intervening emptiness where no matter is found.

But even in such a field of force, both space and the field are still being defined in terms of material objects. Space is still considered as a medium in between objects; and the field at each point is defined as the force that would be exerted upon a particular kind of object, if it were placed at that point. We thus have a mixed conception in which empty space has field properties that transmit force and energy, but these field properties are still defined in terms of matter.

The general theory of relativity has begun to develop a purer, more fundamental concept of field. Here, gravity is not regarded as a force, but as a curvature of space-time. When an apple falls to earth, or when the earth orbits around the sun, such accelerated or curved motion is not regarded as forced. The motion only appears forced, because space-time is itself curved. The motion is following its own natural, straight line in curved space-time. The appearance of forced motion is a manifestation of the geometric curvature of four-dimensional space-time. The gravitational field is thus a geometric conditioning: which is an inherent property of space-time, defined without reference to matter.

As it is presently formulated, the general theory of relativity is of limited application. It is useful for describing the phenomenon of gravity and for our large-scale views of the universe. But it has not developed an effective description of matter itself, nor of forces other than gravity. In the immediate vicinity where matter appears, the equations of general relativity result in what is called a 'singularity'. As one gets closer and closer to a point where matter appears, the gravitational field gets unlimitedly large. At the actual point of material appearance, the gravitational field seems immeasurably and indefinably infinite, so that the description breaks down. The only way to avoid the singularity is to conceive of the material appearance as a 'black hole' or a 'wormhole' that leads off to some other part of space-time.

This suggests a conception of particles as tiny 'wormhole' interconnections in space-time; but the conception has not yet been developed into a useful description of observed material phenomena. Not only is the mathematics difficult; but no effective way has been found for thinking in general relativistic terms about electromagnetic and other such seeming forces that appear in the vicinity of matter. For small-scale descriptions of the world, in the vicinity of matter, modern physicists forget about general relativity, and they use quantum theory instead.

How does quantum theory use the concept of 'field'? Actually, the basic equations of quantum theory, like the Schrodinger wave equation, are essentially field equations. The equations do not describe a quantum system as discontinuous or uncertain in itself. Instead, they describe it as an essentially continuous and well-defined whole, evolving continuously through time in a mathematically well-defined progression of states.

To this mathematical field picture, the Copenhagen interpretation adds the idea of discontinuous and uncertain material observations. This is done by maintaining an alternative material description of the system: with a number of materially observable variables, conceived as though the system were made up of material particles, observed by material instruments.

For each observable variable, the act of observing it is conceived to force the quantum system into one of a special series of states, which are called the 'eigen-states' for that particular variable. Each 'eigen-state' has a special 'eigen-value', which represents the result of the observation. The eigen-state is thus a special state in which the quantum system appears as though it is a definite material system, from the point of view of some particular material observation.

In quantum physics, it is from the act of material observation that discontinuity and uncertainty arise; because the observation forces the system to jump discontinuously to a special eigen-state with a special eigenvalue, and we cannot be sure to which eigen-state the system will jump. In effect, each material observation throws away the richness and subtlety of the field description, by forcing it into an eigen-state that represents a much cruder material appearance.

The trouble with the Copenhagen interpretation is that it makes only a very limited and partial use of the potential subtlety and richness of mathematical field descriptions. It uses this field subtlety only to calculate probability distributions for the much cruder appearances that result from our current material observations. From such probability calculations arises the curious concept of a probability field, for the manifestation of likely appearances.

For example, consider a single photon of light travelling through space. It travels like a wave, according to the Schrodinger wave equation; but when it is observed, it appears as a particle. If it is observed by impinging on a photographic plate, it will appear as a spot. When it appears as a spot on the plate, its location is observed. But where it will appear is uncertain, until the appearance occurs. The Schrodinger equation gives us a probability distribution of where it is likely to appear, when it impinges on the plate. Localities of space and time are thus conditioned by the likelihood of a photon appearing in them; which amounts to a sort of probability field.

It may be noticed that this is a strangely mixed (one might well say 'muddled') concept of field.

- On the one hand, it shows clearly that what we observe are not the definite material objects and particles that appear perceived through our unaided senses and our current measuring instruments.
- On the other hand, it retains these same material concepts that it has disproved; because it describes a probability field which assumes that when we observe things, they are suddenly transformed into material objects, made up from particles.

Given the way that we currently observe things, the probability description of quantum physics is undoubtedly useful. But how fundamental is it? Could it not be an appearance that results from the crudity of our current observations and measuring instruments?

The Copenhagen interpretation involves a double standard: one for what is observed, and another for the instruments of observation.

- For what is observed, there is a relatively subtle field description, which treats quantum systems as though they were made up from waves of oscillating field intensity.
- For our instruments of measurement, there is an unquestioned and unexamined assumption that they are gross, material objects: with gross specifications and producing gross results of observation.

As an example, consider again a photon of light, whose position is observed by its impact on a photographic plate. Schrodinger's equation describes the observed photon as a wave in some subtle kind of field. But in the Copenhagen interpretation, Schrodinger's equation is not applied to the photographic plate, which is the measuring instrument. The plate is simply assumed to be a material object: specified in some gross material way, and observing the photon in a similarly gross way as a spot that has been photochemically altered or otherwise affected materially by the light.

Thus, in the Copenhagen interpretation, the instrument of observation is left out of the field consideration. But an observing instrument (like a photographic plate) is very much a part of the world, just like the other parts of the world that it is used to observe. So, if a field description is applied to what is observed, it should surely apply also to the observing instrument. An instrument like a photographic plate can also be described as a system of field waves.

If we were to describe an instrument in this more subtle way, we would find that our previous gross specification of it was very incomplete. And then we would have a very different view of the act of observation. We would view it as an interaction between two wave systems.

Intuitively, let us consider what happens when two previously separate wave systems come into interaction with one another. They will initially be out of synchronization, but after a transitional phase of mutual adjustment, they could be expected to settle into a combined system with its own internal synchronization. The combined state that results would depend quite sensitively on subtle specifications, like the relative phases of waves across the two previous systems. If an observing instrument is only grossly specified, such subtle specifications would of course be lost. So the results of the observation would appear probabilistic and uncertain, no matter how exactly we specify what is observed.

For example, we could imagine that a photon of light impinging on a photographic plate is rather like lightning striking an area of land. No matter how exactly one specifies the build-up of electric potential in the atmosphere above, the exact place where lightning strikes depends on local variations of conductivity and minor protuberances that require a very detailed specification of the land. Without specifying such details, the location of a lightning strike must seem to be uncertain. Similarly, even where an impinging photon of light is exactly specified in terms of a field description, as long as the photographic plate is not likewise exactly specified, the resultant location of the light-affected spot must seem uncertain and probabilistic.

However, as quantum theory is currently formulated, it cannot describe such an intuitive picture of two field systems interacting so as to result in a combined field system. The reason is that when quantum theory makes a field description, it treats the system it is describing as a complete whole. This is the basic strength of quantum theory. But there is a price to be paid; because the atomic and sub-atomic systems that quantum theory describes are not really complete at all. Though conceived and described as if they are complete, they are in fact very partial.

An inherent problem results. Having described something partial through a complete field description, there is no way of taking anything else into account in that field description. In order to take something else into account, we have first to leave the current field description and return to a gross material view. Then we have to consider how the object originally described relates materially to the something else that is to be taken into account. And from such a material reconsideration, we have to reformulate an entirely new field description of the combined system.

For example, when an electron is considered on its own, its field description is that of a wave pattern which extends through all of space and time; and it thus leaves no room for considering other particles. Similarly, if a proton is considered on its own, its field description leaves no room for other particles, like an electron.

Then how can we consider the situation where an electron, travelling previously on its own, comes near a proton and falls into an atomic orbit, so as to form a hydrogen atom? The answer is that we have to abandon our previous field descriptions of the electron and proton as particles on their own. Instead, we have to consider the two particles as a single system, right from the beginning. In fact, we have to go back to our material view of the world; where we can picture a combined material system of the electron moving under the force of an electrical attraction towards the proton. From this material picture, we reformulate a new field description: of the electron as a wave pattern around the proton. In this new field description, there is a new formulation of Schrodinger's wave equation, and it results in quite a different picture from that of an electron on its own.

In particular, the new picture allows for a discontinuous series of standing wave patterns that form closed orbits around the nucleus. The series is discontinuous because the length of each orbit has to be an integral multiple of the wavelength. Orbits of length in between one multiple and the next are not possible. These closed-orbit wave patterns are interpreted as the possible closed orbits in which the electron can appear, when we switch to a material view.

There is also a continuous series of wave patterns that bend around the nucleus and go on past without forming closed orbits. When switching over to a material view, these open, non-orbiting wave patterns are interpreted as the possible open paths in which the electron may appear.

For an electron to fall from an open path into a closed orbit, its energy level must be lowered and so it has to give off energy to the outside world. But, in our field picture of an electron as a wave pattern around a proton, there is no way of considering such an external interaction. So we must again return to a material view, of an electron as a material particle. This material view has now been altered by the wave picture from which we have returned. We now have only a discontinuous series of allowed orbits that the electron can occupy.

In this altered material view, we can consider an electron falling from a higher energy path to a lower one by giving off a photon of light. This is an essentially discontinuous decrease of energy by the amount contained in the single photon. So we must consider the electron falling from higher to lower energy paths through a discontinuous series of jumps, each corresponding to the emission of one photon (or perhaps more than one).

When the electron falls from one closed orbit to another, the discontinuous series of orbits gives us a discontinuous series of differences in their energy levels; and so the quantity of energy in the emitted photons must match this discontinuous series of energy level differences. Since the energy in a photon depends on its wavelength, this gives us a discontinuous series of wavelengths of light which we should be able to observe being emitted from an atom. Such an altered material picture has in fact proved very useful in our actual observations and technologies.

This is how quantum theory works. It is essentially a way of modifying our material pictures of the world, by a repeated 'flip-flop'. It flips from a relatively crude material picture to a more subtle field picture of some particular situation; and then it flops back to a modified material picture. In itself, the field picture is holistic, continuing and well-defined; but it is built by considering only a partial, material situation. And it is interpreted by returning to a modified material description that is essentially indeterminate and discontinuous, with other things left over to be taken into account. To bring some leftover thing into consideration, there has to be another flip-flop: conceiving another, more complicated field picture and then returning to a further altered material picture that involves more indeterminacy and discontinuity, and is even harder to understand.

For example, in the previous quantum picture of an electron jumping discontinuously from higher to lower energy levels by emitting photons of light, there is uncertainty about when the jumps will take place and which jumps they will be. The interaction between the jumping electron and the photon has been left out of the field description, and it has instead been described only as an uncertain and discontinuous material interaction.

For a more complete and accurate description, the interaction between electrons and protons and photons has to be brought into a combined field description, through some more flip-flops between field and matter views. The result is the theory of quantum electrodynamics, which has indeed turned out to be a little more complete and more accurate; but at the cost of much greater complexity and further conceptual problems: which reduce its clarity and transparency, and make it harder to use and understand.

Thus, as quantum theory tries to build up a picture of the world, from its flip-flop considerations of microcosmic and inherently partial situations, it rapidly comes up against a problem of diminishing returns, in the face of compounding complexity and incomprehensibility.

The basic problem here is the flip-flop duality between matter and field descriptions. The matter description is inherently partial; because it separates the universe into bits of matter which have then to interact through some kind of force. The field description is inherently holistic; because it is concerned with the continuity of space and time, which pervade throughout the world. Each time quantum theory tries to extend one of its microcosmic considerations of some partial situation, it has to abandon its previous field description and return to a complicatedly altered material description, where some more complexity is added by taking something further into account. And then the complexity gets massively compounded, as a new field description is conceived of the extended situation, which is a little more complete but still inherently partial. So the compounding of complexity has to go on, as long as the duality of matter and field remains.

From this analysis of the problem, an obvious question arises. Can quantum theory be complemented by a more fundamental conception, which gives up the apparent duality of matter and field? Can we somehow conceive of a complete field: which would account on the one hand for our macrocosmic views of the universe as a whole, and on the other hand for our microcosmic views of what seem at first to be bits and pieces of matter?

## Macrocosm and microcosm

In trying to conceive a complete field, modern physicists sometimes talk about a 'theory of everything'. Such talk can be rather misleading, to the extent that it suggests some complete and final picture of all objects and situations in the universe. The mistake here is to think that a field conception is made up of objects and situations. A material conception is made up in this way, but a field conception is not. In a field conception, objects and situations are not part of the field. Instead, they are only local appearances or partial views of the field. As we try to conceive a 'complete field', we are looking for a background conception on the basis of which we can co-ordinate, interpret and develop more superficial and partial views of various objects and situations.

For a field to be conceived 'complete', it must be free of all the localization and partiality that is found in our more superficial, material conceptions. In such material conceptions, the space-time continuum is conceived to be somehow broken up into separate localities, like a piece of matter is conceived broken up into separate bits. However, in a pure field conception, free of any material superimposition, we should no longer conceive of any locality as a separate bit or piece of the continuum. Instead, it needs to be considered as an alternative appearance or view of the whole continuum. In other words, where a material conception is inherently partial because it looks at its parts as separate pieces of a made-up whole, we need a pure field conception where each part is conceived as just another appearance or another view of the same, underlying reality.

Mathematically, this means that the field must be ‘self-similar’. The whole field must be ‘similar’ to each of its localities, and every locality must be ‘similar’ to each of the others. There must be a mathematical transformation which provides a one-to-one mapping between the whole field and each locality, and between any two localities. Each locality would then be a mathematical transformation of the whole field and of each other locality.

Conceptually, this means that when we consider any locality in the universe, we do not stop at any material object or situation that we may perceive here. Instead, we consider the object or situation as what appears prominently in the foreground of this locality, because of our inexact perception. If we examine the locality more and more exactly, there is to be discovered a background of finer and finer details in which the whole universe is ultimately mirrored. This is of course a very old conception, of the universe mirrored in each of its microcosms.

In modern physics, this macrocosm-microcosm correspondence is simply an extension of the principle of relativity: that whatever is conceived fundamental must always be the same, no matter how differently it may be viewed. Or, to put it more formally, the basic laws and principles of physics must be invariant, through the variation of relative views. Up to now, in the special and general theories of relativity, modern physicists have only considered those differences of viewpoint that arise from the observer’s state of motion. But our differences of view do not just arise from how differently we travel. They also arise from the different locations towards which we look. An observer does not look everywhere, but only at a particular locality. And yet, through our differing views of varying localities, we see the same, invariant reality underlying all the appearances that we perceive. So each such local view is simply a relative appearance of this one same reality, throughout the whole universe.

To take into account this variation of local views – as relative appearances of the same, complete reality – we have to conceive of a basic correspondence between macrocosm and microcosm: as an inherent property of the space-time field. And the basic laws and principles of physics will have to be invariant: through the mathematical transformations which show that the macrocosmic field and all its localities are only differing views of one same reality, represented by the mutual correspondence between them.

Such a complete field conception will require a new kind of mathematics, which is just beginning to be developed in chaos and complexity theories. The problem is that so much current mathematics involves the differential calculus, which makes an assumption of eventual simplicity at small scales of size. The macrocosm-microcosm correspondence contradicts this assumption, because it requires complexity to remain unchanged at all scales, no matter how small. So some radical development will be needed in modern mathematics, before it can be effectively used to describe a complete field conception.

However, we can perhaps speculate some sort of intuitive picture, by considering that a complete field conception must account for both the particle and the wave appearances of matter. From the general theory of relativity, it appears that a particle might be conceived as the appearance of a 'wormhole' interconnection to some other part of space-time. But the wormhole itself must be made up of space-time paths, just like the rest of the continuum. And these space-time paths would imply the appearance of smaller particles travelling through the wormhole. The smaller particles would in turn show smaller wormhole interconnections branching off the bigger wormhole through which the smaller particles appear to travel. We thus get a picture of endlessly branching wormhole interconnections in the space-time continuum. And the wave appearance of matter could result from oscillating patterns in the continuum and its infinitely branching network of interconnections.

However, any such conception of the physical universe must inevitably become mind-boggling, as it builds a picture of mounting complexity from the very partial and limited perceptions of our physical senses. So, as we interpret our physical conceptions, and as we relate them to broader experiences that include life and mind, is there a simpler and more direct way of thinking about reality? Yes there is, by reflecting attention back: from outward thought of an external universe, towards our more direct experience of perception and knowledge.

For a start, if we consider our experience of physical perception, it gives us another way of looking at the correspondence between macrocosm and microcosm. For we always view the universe through some more immediate neighbourhood.

For example, consider someone who is in a room, looking through a window at the world outside. Everything directly perceived is actually in the room. What the observer directly sees and hears are patterns of light and sound that are inside the room at the actual time of their perception. What the observer smells and tastes and touches are gases or liquids or solids that are likewise in the room at the time when they are tasted or smelled or touched. So, for the observer in a room, the world outside must always be interpreted through the microcosm of the room.

The observer's perceptions of a world outside are fundamentally dependent upon a macrocosm-microcosm correspondence, through which immediate perceptions are interpreted so as to conceive more distant things. We never perceive the world apart from this correspondence; and so it is fundamental to our experience and our conceptions of the world.

But it would be ridiculous to think this correspondence belongs only to our immediate surroundings; because we happen to have graced them with our presence or our attention, or because we have specially developed them (by bringing in instruments of observation) so as to make the correspondence apparent to us. If it is to be a reliable basis for our conception of the world, this macrocosm-microcosm correspondence must apply to all localities, however near or distant; not just to those that are graced by someone's personal presence or attention.

## Consciousness

If attention is reflected further back, from objective physical perception into our subjective experience of mind, the concept of reality may be approached in a much more direct way. In such a direct approach, thought is turned back upon itself, through an enquiry into its own ground. Instead of further building up its conceived pictures of an external universe, thought is used to enquire back, into the underlying ground upon which our conceptual pictures are built.

When thus reflectively approached, through a direct return to it, this ground is called 'consciousness'. It is here viewed as that common subjective principle which underlies all states of experience, all perceptions, thoughts and feelings. This is the one, invariant reality of all subjective experience.

But ultimately, all experience is subjective. Everything that anyone experiences – anywhere or at any time in the universe – is always experienced subjectively: through perception, thought and feeling. So consciousness always underlies all appearances, throughout the universe. In this ultimate, philosophical sense, consciousness is the ground of all reality.

'Consciousness' and 'reality' are only two words for what is ultimately the same thing. As we look out to it through objective appearances, we call it 'reality'. As we return to it in our subjective experience of knowing, we call it 'consciousness'. There is thus a final non-duality: between consciousness that knows and the reality that is known.

This non-duality is usually obscured, by a habitual confusion about what consciousness is. The trouble is that we habitually identify consciousness as a personal faculty, which belongs to a person's body and mind. Thus we split each person's experience into two. On the one hand, there is a knowing consciousness, with physical and mental characteristics. On the other hand, there is a known world, made up of the physical and mental objects that consciousness sometimes knows and sometimes fails to know.

With consciousness thus personally identified as knowing a physical and mental world outside itself, there appear to be many consciousnesses: belonging to many persons, at many places and many times. Each personal consciousness appears as a particular instrument in the world: acting as a particular object upon other objects, and hence involved in the world's objective activities.

But there is an unexamined confusion here. In everyone's experience, all appearances are illuminated by consciousness. Objects, instruments and activities appear and disappear; but all their appearances and disappearances are lit by consciousness. It is the common, illuminating principle that is present through all experience, no matter what appears or disappears. It cannot be an instrument or a faculty or an activity of any kind, neither physical nor mental.

For all instruments and faculties and activities, whether physical or mental, are objects that appear in experience when they are perceived; and they disappear from experience when they are not perceived. So our habitual identification of consciousness, as a personal faculty, is a misleading confusion that needs to be cleared.

Instead of being a personal faculty, with physical or mental characteristics, consciousness is that one principle, in everyone's experience, which does not appear or disappear. Appearances and disappearances arise from perception; but perception arises from underlying consciousness, which lights all perception from beneath: from below all perceived appearances and disappearances.

As it continues beneath the surface of perceived appearances, consciousness has no divisions in it, nor any physical or mental characteristics of name or form or quality. For all divisions and characteristics have to be perceived, in order that they may appear. They belong to the changing surface, not to the consciousness that continues beneath.

Since it has no divisions or characteristics, there is no way of distinguishing consciousness as somehow different in the differing experiences of different people, nor at differing moments of time. One same consciousness is always present: as the underlying ground of all appearances, in everyone's experience, at each moment of time.

It is in this sense that consciousness is the final ground of reality, beneath all pictures of the world. Each picture is made up of various bits and pieces, which are the objects and happenings that occur in the pictured world. And these bits and pieces of the picture are put together through relationships of pattern and causality: as objects are conceived to act upon each other, and as happenings are conceived to flow causally from the past into the future.

Thus, each picture of the world is like a varying horizontal surface, superimposed upon the invariant and unpictured ground of underlying consciousness. Along the superimposed surface, the picture changes horizontally, from one object to another and from one happening to another. And this pictured variation is regulated by horizontal patterns of interaction and horizontal chains of cause and effect which are also part of the picture.

But consciousness underlies the whole picture and every part of it. Each object and happening in the picture is a piece of perception or conception: which arises from consciousness, as it appears in experience. Each relationship of pattern, each chain of cause and effect is a linking piece of perception or conception: which likewise arises from consciousness. The whole picture is an overall conception: which also must arise from consciousness, whenever it appears in experience.

This same consciousness gives rise to everything that we perceive or conceive, in all our pictures of the world. From consciousness arises every object and happening, every pattern or causal relationship, and the entire world.

But this is a '*vertical*' arising: from underlying consciousness into a superimposed picture. It is quite different from any '*horizontal*' action or causation that occurs along the surface of the picture. Consciousness is never any part or any element in any picture of the world. It is always *beneath* the picture, quite unaffected and unchanged by the changes that take place *in* the picture (along the horizontal surface of names, forms and qualities).

From the standpoint of consciousness, there is no changing picture. Everything in the picture is an appearance, which is nothing but consciousness. There is no real difference between the picture and consciousness; so there is truly no horizontal change, nor is there any vertical change or arising.

It is only when one starts from some picture of the world, and reflects back to consciousness, that one needs to think of the pictured world as having arisen from an underlying ground of consciousness. And here, when reflecting back to consciousness, it must be seen as completely out of the picture: completely detached from the objects and happenings of the changing world.

From beneath the world picture, consciousness never intervenes or interferes. It is not involved in any activity or change. All movement, all activity and change are part of the world picture: taking place through its horizontal causation, without any intervention or interference from underlying consciousness.

And yet, through the vertical arising of the picture and each of its parts, consciousness is *expressed* in all objects and happenings in the world. This vertical arising, or 'expression of consciousness', is never an interference of any kind; because it is quite unlike the action of one object or happening upon some other object or happening. An object or a happening acts through some kind of force or influence, exerted across dividing boundaries, in the course of time. But consciousness is expressed quite naturally and spontaneously – without any exertion of force or influence – from beneath all boundaries and divisions of space and time.

This vertical expression gives our pictures of the world their life and meaning. It is their natural complement: which does not interfere with their patterns of horizontal causation, but enables us to understand them.

For example, a thought may be considered objectively, as an abstract idea: made up of component ideas, and part of an abstract structure or a causal train of ideas. But such an abstract picture of thought is dry and lifeless, and essentially meaningless, until it is completed by a subjective realization of thought: as expressing consciousness. It is only then that abstracted ideas are filled with life and meaning, and thought is properly understood.

The same is true for a living body. It may be considered objectively, as a physical object: made up of physical parts, and itself taking part in an external world of physically caused activity. But for such a physical picture to have life and meaning, it must be complemented by the subjective realization that the living body expresses consciousness. Only then can a body be properly understood as meaningful and alive.

The same is true again for a symbolic object, like a word. It may be understood objectively: as made up of symbolic components like letters, and itself taking part in structures and chains of symbolic action, like sentences and paragraphs. But no such symbolic picture can have any life or meaning, nor can it be properly understood, without subjectively realizing it: as an expression of consciousness. Without such a subjective realization, a word or a sentence must remain a meaningless string of letters.

The same is true even for an object like a rock, which does not appear to be either living or symbolic. For the rock to be understood, it must have some kind of meaning. Its internal structure must have some meaningful order, and it must take part in an external world of meaningfully ordered structure and activity. The order that is found in both rock and world can be described abstractly, through abstract patterns of structure and causation; but any such abstract description must have some sort of meaning, for it to be understood. And this meaning must involve some expression of consciousness.

In the case of a purely physical object like a rock, no consciousness is apparently involved; until we consider that the object must be observed before it can appear in anyone's experience. So there is a strong temptation to conceive that the object itself is independent of consciousness; until some observer comes along and personally brings consciousness to bear upon the object, thus enabling it to be perceived and thought about and understood.

But this conception of an independent object is entirely based upon the confused assumption that consciousness is a personal function, belonging to an observing body and mind. When consciousness is more clearly seen as the impersonal ground of the whole picture, including each observer and everything observed, then it becomes evident that consciousness is expressed not only in an observer but also in every object that is physically or conceptually observed. The observed object is understood by a reflection back to that same impersonal ground of consciousness which is expressed not only in the personalities of various observers, but everywhere in the observed world.

When we think of a living creature, we conceive an explicit and personal expression of consciousness, in that creature's physical and mental activities. In the science of physics, all such explicit expression of consciousness is excluded from the field of study. So, physics does not consider objects and happenings as personalized expressions of consciousness. By its very nature, as it focuses attention on the physical aspect of experience, the science of physics does not consider consciousness explicitly. Instead, it describes objects and happenings in relation to each other, and hence in relation to the structural and causal patterns that they form. Thus it builds its physical pictures of the world, independent of the explicit and personalized expressions of consciousness that are considered in other disciplines and in everyday life.

As an objective science, physics progresses through a search for more accurate and complete pictures, with a better determined account of the universal order that puts together our particular bits and pieces of perception and conception. This progressive search for greater determination and certainty is fundamental to physics. It is the essential way in which physics approaches reality. Any claim to have determined some final limit of determination is tantamount to claiming that a final, objective end has been found, beyond which physics cannot go.

But the true indeterminacy of physics is that it cannot determine any final end to its progress. As it approaches reality, it must keep transforming its pictures and descriptions, without reaching any final, objective end. There is no true 'theory of everything', nor any final 'end of physics', to be objectively found.

The reason for this is that physics makes objective pictures of a reality that is not finally objective. Physics describes reality as though it were objective; but the basis of the description is each physicist's own consciousness, which is finally subjective. For a better understanding of what has been observed, a physicist reflects more fundamentally back, into the underlying ground of consciousness from which all descriptions arise. This reflection back is a tacit acknowledgement that the reality which is known must fundamentally be the same as the consciousness which knows.

Thus, while physics describes the world as explicitly objective, each physicist tacitly acknowledges reality as fundamentally subjective, each time a description is understood. When something goes wrong with a current picture of the world, physicists question their current assumptions and thus reflect back into the depth of their subjectivity; from which a new picture arises, with new ways of understanding and looking at the world.

The new understanding gets expressed in the development of new instruments of observation and interaction with the world. In their turn, the new instruments and observations show us something more about the world. This something more that is observed eventually outgrows the new picture that gave rise to it; and so the cycle repeats itself, with another new picture giving rise to further understanding and observation.

For as long as we can see back into history, repeated cycles of learning have kept transforming our pictures of the world. There has always been a temptation to look at some current picture as the final one; and giving in to the temptation has always been proved a mistake.

Does this mean that there is no ‘reality’, shown by our endlessly changing pictures of the world? Not necessarily. It only means that reality does not belong exclusively to any particular picture. Reality is not found in the changing surface of any picture, but beneath it.

And beneath the changing surface, reality is nothing but the changeless ground of consciousness, where subject and object are one. On this non-dual ground, all physics is based, like any other form of learning.

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