What is Reality?

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What do we understand by "reality"? For those of us who consider ourselves hard-headed realists, there is a kind of common-sense answer: "Reality consists of those things—tables, chairs, trees, houses, planets, animals, people and so on—which are actual things made of matter." We might tend to include some more abstract-seeming notions such as space and time, and the totality of all such "real" things would be referred to as "the universe".

Some might well consider that this is not the whole of reality, however. In particular, there is the question of the reality of our minds. Should we not include a conscious experience as something real? And what about concepts, such as truth, virtue or beauty? Of course, some hard-headed people might adopt a doggedly materialist point of view and take mentality and all its attributes to be secondary to what is materially real. Our mental states, after all (so it would be argued), are simply emergent features of the construction and behaviour of our physical brains.

We behave in certain ways merely because our brains act according to physical laws—the same laws as those that are strictly obeyed by all other pieces of physical material. Conscious mental experience, accordingly, has no further reality than that of the material underlying its existence; though not yet properly understood, it is merely an "epiphenomenon", having no additional influence on the way that our bodies behave beyond what those physical laws demand.

Some philosophers might take an almost opposite view, arguing that it is conscious experience itself that is primary. From this perspective, the "external reality" that appears to constitute the ambient environment of this experience is to be understood as a secondary construct that is abstracted from conscious sense-data. Some might even feel driven to the view that one's own particular conscious experience is to be regarded as primary, and that the experiences of others are themselves merely things to be abstracted, ultimately, from one's own sense-data.

I have to confess to having considerable difficulty with such a picture of reality, which seems to me lopsided. At best, it would be difficult to convince anyone else of a theory of reality that depended upon such solipsism for its basis. Moreover, I find it extremely hard to see how the extraordinary precision that we seem to observe in the workings of the natural world should find its basis in the musings of any individual.

Even if such a solipsistic basis is not adopted, so that the totality of all conscious experience is to be taken as the primary reality, I still have great difficulty. This would seem to demand that "external reality" is merely something that emerges from some kind of majority-wins voting amongst the individual conscious experiences of all of us taken together. I cannot see that such an emergent picture could have anything like the robustness and precision that we seem to see outside ourselves, stretching away seemingly endlessly in all directions in space and in time, and inwards to minute levels that we do not directly perceive with our senses; all requiring many different kinds of precision instruments to explore the universe over a vast range of different scales.

True, there is a mystery about consciousness itself, and it is profoundly puzzling how it could come about from the seemingly purely calculational, unfeeling and utterly impersonal laws of physics that appear to govern the behaviour of all material things. Nevertheless, among the basic laws of physics that we know—and we do not yet know all of them—some are precise to an extraordinary degree, far beyond the precision of our direct sense experiences, or of the combined calculational powers of all conscious individuals within the ken of mankind.

One example of an over-reachingly deep and precise physical theory is Einstein's magnificent general theory of relativity, which improves even upon the already amazingly accurate Newtonian theory of gravity. In the behaviour of the solar system, Newton's theory is precise to something like one part in 107: Einstein's theory does much more, giving not only corrections to Newton's theory that become relevant when gravitational fields get large, but also predicting completely new effects, such as black holes, gravitational lensing and gravitational waves—the analogues, for gravitation, of the light waves of Maxwell's electromagnetic theory. The agreement between theory and experiment here has been extraordinary. Astronomers have, for example, been monitoring the orbits of one double neutron star system—known as PSR 1913+16—for around 40 years. The emission of Einstein's predicted gravitational waves from this system has been confirmed through a very gradual shortening of the stars' orbital period, and there has been an agreement between the signals received from space and the overall predictions of Einstein's theory to an astonishing 14 decimal places. At the other end of the size scale, there are multitudes of very precise observations that give innumerable confirmations of the accuracy of quantum theory and also of its generalisation to the quantum theory of relativistic fields, which gives us quantum electrodynamics. The magnetic moment of an electron, for example, has been precisely measured to some 11 decimal places, and the observed figures are matched precisely by the theoretical predictions of quantum electrodynamics.

An important point to be made about these physical theories is that they are not just enormously precise but depend upon mathematics of very considerable sophistication. It would be a mistake to think of the role of mathematics in basic physical theory as being simply organisational, where the entities that constitute the world just behave in one way or another, and our theories represent merely our attempts—sometimes very successful—to make some kind of sense of what is going on around us. In such a view there would be no particular mathematical order to the world; it would be we who, in a sense, impose this order by describing, in an elaborate mathematical scheme, those aspects of the world's behaviour that we can make sense of.

To me, such a description again falls far short of explaining the extraordinary precision in the agreement between the most remarkable of the physical theories that we have come across and the behaviour of our material universe at its most fundamental levels. Take, for another example, that most universal of physical influences, gravitation. It operates across the greatest reaches of space, but as early as the 17$^{\text{th}}$ century Newton had discovered that it was subject to a beautifully simple mathematical description. This was later found to remain accurate to a degree that is tens of thousands of times greater than the observational precision available to Newton. In the 20$^{\text{th}}$ century, Einstein gave us general relativity, providing insights at a yet deeper level.

This theory involved considerably more mathematical sophistication than

Newton's: Newton had needed to introduce the procedures of calculus in order to formulate his gravitational theory, but Einstein added the sophistication of differential geometry—and increased the agreement between theory and observation by a factor of around 10 million. It should be made clear that, in each case, the increased accuracy was not the result of a new theory being introduced only to make sense of vast amounts of new data. The extra precision was seen only after each theory had been produced, revealing accord between physical behaviour at its deepest level and a beautiful, sophisticated mathematical scheme.

If, as this suggests, the mathematics is indeed there in the behaviour of physical things and not merely imposed by us, then we must ask again what substance does this "reality" that we see about us actually have? What, after all, is the real table that I am now sitting at actually composed of? It is made of wood, yes, but what is wood made of? Well, fibres that were once living cells. And these? Molecules that are composed of individual atoms. And the atoms? They have their nuclei, built from protons and neutrons and glued together by strong nuclear forces; these nuclei are orbited by electrons, held in by the considerably weaker electromagnetic forces. Going deeper, protons and neutrons are to be thought of as composed of more elementary ingredients, quarks, held together by further entities called gluons. Just what are electrons, quarks and so on, though? The best we can do at this stage is simply to refer to the mathematical equations that they satisfy, which for electrons and quarks would be the Dirac equation. What distinguishes a quark from an electron would be their very different masses and the fact that quarks indulge in interactions—namely the "strong" interactions—that electrons are blind to. What, then, are gluons? They are "gauge" particles that mediate the strong force—which is again a notion that can only be understood in terms of the mathematics used to describe them.

Even if we accept that an electron, say, should be understood as being merely an entity that is the solution of some mathematical equation, how do we distinguish that electron from some other electron? Here a fundamental principle of quantum mechanics comes to our rescue. It asserts that all electrons are indistinguishable from one another: we cannot talk of this electron and that electron, but only of the system, which consists of a pair of electrons, say, or a triple or a quadruple, and so on. Something very similar applies to quarks or gluons or to any other specific kind of particle. Quantum reality is strange that way.

Indeed, quantum reality is strange in many ways. Individual quantum particles can, at one time, be in two different places—or three, or four, or spread out throughout some region, perhaps wiggling around like a wave. Indeed, the "reality" that quantum theory seems to be telling us to believe in is so far removed from what we are used to that many quantum theorists would tell us to abandon the very notion of reality when considering phenomena at the scale of particles, atoms or even molecules.

This seems rather hard to take, especially when we are also told that quantum behaviour rules all phenomena, and that even large-scale objects, being built from quantum ingredients, are themselves subject to the same quantum rules. Where does quantum non-reality leave off and the physical reality that we actually seem to experience begin to take over? Present-day quantum theory has no satisfactory answer to this question.

My own viewpoint concerning this—and there are many other viewpoints—is that present-day quantum theory is not quite right, and that as the objects under consideration get more massive then the principles of Einstein's general relativity begin to clash with those of quantum mechanics, and a notion of reality that is more in accordance with our experiences will begin to emerge. The reader should be warned, however: quantum mechanics as it stands has no accepted observational evidence against it, and all such modifications remain speculative. Moreover, even general relativity, involving as it does the idea of a curved space-time, itself diverges from the notions of reality we are used to.

Whether we look at the universe at the quantum scale or across the vast distances over which the effects of general relativity become clear, then, the common-sense reality of chairs, tables and other material things would seem to dissolve away, to be replaced by a deeper reality inhabiting the world of mathematics. Our mathematical models of physical reality are far from complete, but they provide us with schemes that model reality with great precision—a precision enormously exceeding that of any description that is free of mathematics.

There seems every reason to believe that these already remarkable schemes will be improved upon and that even more elegant and subtle pieces of mathematics will be found to mirror reality with even greater precision. Might mathematical entities inhabit their own world, the abstract Platonic world of mathematical forms? It is an idea that many mathematicians are comfortable with. In this scheme, the truths that mathematicians seek are, in a clear sense, already "there", and mathematical research can be compared with archaeology; the mathematicians' job is to seek out these truths as a task of discovery rather than one of invention. To a mathematical Platonist, it is not so absurd to seek an ultimate home for physical reality within Plato's world.

This is not acceptable to everyone. Many philosophers, and others, would argue that mathematics consists merely of idealised mental concepts, and, if the world of mathematics is to be regarded as arising ultimately from our minds, then we have reached a circularity: our minds arise from the functioning of our physical brains, and the very precise physical laws that underlie that functioning are grounded in the mathematics that requires our brains for its existence. My own position is to avoid this immediate paradox by allowing the Platonic mathematical world its own timeless and locationless existence, while allowing it to be accessible to us through mental activity. My viewpoint allows for three different kinds of reality: the physical, the mental and the Platonic-mathematical, with something (as yet) profoundly mysterious in the relations between the three.

We do not properly understand why it is that physical behaviour is mirrored so precisely within the Platonic world, nor do we have much understanding of how conscious mentality seems to arise when physical material, such as that found in wakeful healthy human brains, is organised in just the right way. Nor do we really understand how it is that consciousness, when directed towards the understanding of mathematical problems, is capable of divining mathematical truth. What does this tell us about the nature of physical reality? It tells us that we cannot properly address the question of that reality without understanding its connection with the other two realities: conscious mentality and the wonderful world of mathematics.

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