A New Conception of Science

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When scientists choose one theory over another, they reject out of hand all those that are not simple, unified or explanatory. Yet the orthodox view of science is that evidence alone should determine what can be accepted. Nicholas Maxwell thinks he has a way out of the dilemma.

There is one point about the nature of science on which almost all scientists agree. In science evidence *alone* determines what is to be accepted as scientific knowledge. Nothing substantial about the nature of the universe can be accepted permanently as a part of scientific knowledge
independently of evidence, let alone in violation of the evidence. Considerations that have to do with the simplicity, unity or explanatory power of theories may influence scientists in deciding what theories to accept and reject. But this does not mean, according to this orthodox view, that science assumes permanently that the universe itself is simple, unified, or comprehensible.

This orthodox conception of science, taken for granted by the scientific community and the public alike, exercises an immense influence over the way science is pursued, taught and understood. But it is untenable! Elementary considerations show that science cannot proceed in this way.

Orthodoxy refuted

Given any scientific theory, however well verified empirically, there will always be infinitely many rival theories which fit the available evidence just as well, but which make different predictions, in an arbitrary way, for as yet unobserved phenomena.

For example, Newtonian theory (NT), has, as one such rival, a theory which asserts that everything occurs according to NT until midnight, at which point gravitation abruptly becomes a repulsive force. Another rival theory asserts that everything occurs according to NT except for systems consisting of 1000 tonne gold spheres in a spherical region of outer space of 1 mile radius, in which case gravitation obeys an inverse cube law. Grossly ad hoc rival theories of this type can be made even more empirically successful than NT by adding on postulates which, independently, make successful empirical predictions. (A theory is ad hoc if it asserts that for some specific kind of phenomenon quite different laws hold.)

One could set out to refute these ad hoc rival theories experimentally, but this would need an infinitely long time to complete because there are infinitely many such theories. So, if science really did take seriously the idea that evidence alone decides what theories are to be accepted and rejected, scientific knowledge would be drowned in an infinite ocean of empirically equally successful rival theories. Science would come to an end.

Why does this not happen in scientific practice? The reason is that, in practice, two considerations govern the acceptance and rejection of theories in science: first, considerations of empirical success and failure; and second, considerations that have to do with the simplicity, unity or explanatory power of the theories in question. To be accepted as a part of scientific knowledge, a theory must satisfy both considerations. In other words, it must be both empirically successful and simple, unified, or explanatory in character.

Theories accepted as a part of scientific knowledge – including NT, classical electromagnetism, quantum theory and Einstein's theories of special and general relativity – satisfy (more or less adequately) both considerations. They are amazingly successful in their capacity to predict
observable phenomena, and at the same time they are astonishingly simple, unified and explanatory.

However, the infinitely many empirically successful rivals to these accepted theories all fail to satisfy the second consideration. In other words, they may fit all available evidence just as well as - or even better than - NT or Einstein's theories, but they fail, quite drastically, to be simple, unified and explanatory. These rival theories all assert that, for some as yet unobserved kind of phenomenon, something entirely peculiar and arbitrary occurs. These rivals, which have not as yet been refuted empirically, are rejected by scientists, not on empirical grounds, but because they are grotesquely ad hoc, and grotesquely lacking in simplicity, unity and explanatory power.

This is why science is not, in practice, buried beneath an infinite mountain of rival theories, all of which fit all available evidence just as well as accepted theories, if not better. The reason is that almost all of the rivals are horribly ad hoc.

But now comes the decisive point. In persistently rejecting infinitely many such empirically successful but grotesquely ad hoc theories, science is in effect making a big permanent assumption about the nature of the universe, to the effect that it is such that no ad hoc theory is true, however
empirically successful it may appear to be for a time. Without some such big, permanent assumption as this, the empirical method of science collapses. Science is drowned in an infinite ocean of empirically successful ad hoc theories. However, as we saw above, the key thesis of the orthodox view is that science must make no permanent assumption about the nature of the universe, independently of evidence. Thus, this orthodox conception of science is untenable.

Hierarchy of assumptions required

So if science must make some kind of big assumption about the nature of the universe to be possible at all, what precisely ought it to be, and on what basis is it to be made?

My proposed solution to this fundamental problem confronting the scientific enterprise is set out in my book *The Comprehensibility of the Universe* (Oxford University Press, 1998). My solution has not yet been generally accepted, but it goes something like this. We need to see science as adopting a “hierarchy” of increasingly insubstantial cosmological assumptions concerning the comprehensibility and knowability of the universe. At the top of the hierarchy there is the assumption that the universe is such that it is possible for us to acquire some knowledge of something - an assumption so insubstantial that it could not be rational for us to reject it in any circumstances whatsoever. Lower down in the hierarchy we adopt those assumptions which appear to be the most fruitful from the standpoint of promoting the growth of empirical scientific knowledge. These include the assumption that the universe is comprehensible in some way or other and, more specifically, and next down in the hierarchy, the assumption that the universe is *physically* comprehensible. Those scientific theories that are accepted are the ones that are most successful empirically, and that best accord with the best available assumptions concerning the comprehensibility and knowability of the universe.

What does it mean to assert that the universe is comprehensible? It means that the universe is such that there is “something” - God, a tribe of gods, a cosmic goal, a pattern of physical law, a cosmic programme or whatever - that exists everywhere in an unchanging form. It means, furthermore, that the ubiquitous “something” determines or is responsible for, in some sense, everything that changes. As a result, all change and diversity in the world can, in principle, be explained and understood in terms of the underlying, unchanging “something”. If the “something” that determines all change is a unified pattern of physical law, then the universe is said to be *physically* comprehensible. The universe is physically comprehensible, in other words, if it is in principle possible for us, one day, to formulate a unified "theory of everything" which is true. Physical comprehensibility is a special case of the more general idea that the universe is comprehensible in some way or other.

Physical comprehensibility

As an elementary example of a possible universe that is physically comprehensible, consider a universe that consists of nothing but the classical electromagnetic field in the vacuum (there being no charged particles to create, or be acted on, by the field). In this rather bleak universe it is the values of the electric and magnetic fields that vary from place to place and time to time. The physical “something” that does not change but that determines all change is the property of the electromagnetic field, the same everywhere, that determines that the electric and magnetic fields change according to Maxwell's equations for the classical electromagnetic field in the vacuum.

Why is it legitimate in this case to regard the field as one unified entity (the electromagnetic field) and not two distinct entities - the electric field and the magnetic field? In part, unity arises from the symmetrical way in which changes in the electric field produce a magnetic field, and changes in the magnetic field produce an electric field. But even more important, unity arises from the fact that the way the electromagnetic field divides into the electric field and the magnetic field differs for different reference frames travelling at uniform velocity with respect to each other. (Ignore the awkward point that this universe does not contain reference frames.) However, according to Einstein's special theory of relativity, nothing of absolute (or theoretically fundamental) significance can depend on choice of reference frame. We cannot regard the electromagnetic field as being made up of two distinct fields (the electric and magnetic fields) because any specific choice of electric and magnetic field would be arbitrary, in that it would amount to an arbitrary choice of reference frame. In short, the electromagnetic field is unified because it exhibits the symmetry, postulated by special relativity, of Lorentz invariance.

Symmetry is, in general, an important feature of unity, and thus of physical comprehensibility. In requiring of a fundamental physical theory that it satisfies a symmetry principle (such as Lorentz invariance) or a global or local gauge symmetry, we are, in effect, demanding that the theory
accords with a more or less specific conception of unity and physical comprehensibility.

For the universe to be physically comprehensible, it must, in short, have a unified dynamic structure. It must consist of one kind of entity that interacts by means of one kind of force. The theory that depicts this unified structure must satisfy appropriate symmetry principles. The more the
universe departs from these requirements, the more physically incomprehensible it becomes.

The new orthodoxy?

By adopting this hierarchy of increasingly insubstantial cosmological assumptions, we maximize our chances of adopting assumptions that promote the growth of knowledge and minimize our chances of taking some cosmological assumption for granted that is false and impedes the growth of knowledge. The hope is that as we increase our knowledge about the world we improve the (lower level) cosmological assumptions implicit in our methods, and thus in turn improve the methods themselves – that is principles which specify symmetries that acceptable theories must exhibit.

By improving our knowledge, we improve our knowledge about how to improve our knowledge. Science adapts its own nature to what it learns about the nature of the universe, thus increasing its capacity to make progress in knowledge about the world. In particular, this hierarchical view leads to a rational, if fallible, method for discovering new fundamental physical theories. Roughly speaking, this method states that when existing fundamental physical theories clash with one another, we should modify our ideas about such things as space, time, force and physical entities (i.e. particle or field), in an attempt to depict a new kind of underlying theoretical unity that, in turn, leads to a new unifying physical theory.

Something of all this can be discerned in the way Einstein discovered special relativity and general relativity. Both theories arose out of Einstein's search for unity. In the case of special relativity, Einstein sought to resolve the clash between Newton's particle-based "action-at-a-distance" theory and Maxwell's field theory. In the case of general relativity he sought to resolve the clash between Newtonian theory and special relativity. In both cases Einstein formulated physical principles which are also methodological: the principle of relativity in the case of special relativity and that of equivalence in the case of general relativity. Einstein was also led to modify pre-existing ideas about space and time. In the case of special relativity, Newtonian notions of space and time were modified to form the notion of Minkowskian space-time. In the case of general relativity, flat space-time becomes curved.
(For details see N. Maxwell 1993 *British J. Philosophy Sci.* **44** 275: http://philpapers.org/profile/17092 .)

This way of doing theoretical physics, which was created by Einstein, has had an immense impact on subsequent physics. Despite this, physicists still pay lip service to the untenable orthodox conception of science with which we began. Nearly a century after Einstein did his work, it is about time the "hierarchical view" became the new orthodoxy. We need a revolution in our understanding of science.

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