The incompatibility of Popper's philosophy of science with genetics and molecular biology

Sir,

The late Karl Popper is widely regarded as the most important of all philosophers of science. In 1972 Peter Medawar said "I think Popper is incomparably the greatest philosopher of science that has ever been." Other leading scientists, such as Jacques Monod, John Eccles, and Herman Bondi, have expressed similar views. One of Popper's main conclusions is that everything achieved by science is, in principle, falsifiable. This had lead to a common view that nothing in science is certain, as there is always the possibility that a scientific law or conclusion will be proved wrong. A widely cited example of this is Newton's description of the universe, which held sway for over 300 years, until this century. Even Herman Bondi has been reported to have said of Newtonian theory: "We may certainly speak of disproof now" (cited in Ref. 1).

Such an extreme view can be attributed to Popper's philosophy of science, as expounded in *The Logic of Scientific Discovery* (published in German as *Logik der Forschung* in 1935, and in English in 1959.[2] For a lucid summary, see Ref. 3). His starting point is David Hume's criticism of the inductive method of observation and conclusion. A common example, and used by Popper himself, is that no matter how many white swans are observed, we cannot conclude that all swans are white. The observation of a single black swan disproves the conclusion. This has come to be known as "the problem of induction," and it has been of constant concern to philosophers that science, which is eminently successful, might be based on a method or on reasoning which is not logical. Popper claimed to have solved the problem of induction. Indeed, he said that induction is irrelevant to the pursuit of science; it does not exist; it is a myth.

In essence, Popper concludes that no scientific hypothesis, theory, or law can be fully verified, but it can always be refuted. Science proceeds by attempts to refute a hypothesis, and every time such an attempt fails, the hypothesis is strengthened. Observations and experiment lead to the modification and refinement of hypotheses or theories, but never to final proof. The principle of falsification always remains.

Most philosophers of science, including Popper, take their examples from physics. There is no discussion of chemistry or biology in *The Logic of Scientific Discovery*. It is precisely in these areas that Popper's analysis of the scientific method is found to be itself falsifiable. Consider first the classical discovery by Harvey of the circulation of the blood. There is no way that the fact of the circulation of the blood could be shown to be false. Indeed, we can be sure that all vertebrates have such circulation without the need to examine each one. To reach his conclusion, Harvey successfully used a combination of observation and deduction. Genetics provides a more modern example of the way science actually advances. Mendel discovered two fundamental laws of inheritance in one plant species. From this, he could certainly not extrapolate to all species, plant and animal. When his work was rediscovered 30 years after it was published, other scientists confirmed his observations in several other plant and animal species. This established a corpus of knowledge, known as genetics, which is based on Mendel's original laws. Mendelian inheritance is that which follows these laws. We now know that plants and animals have many other common features, including cells with a nucleus containing chromosomes, cell division by mitosis, and the production of haploid cells from diploid ones by meiotic division. With this information we know that inheritance in the elephant is the same as in other animals. We do not need to actually study the genetics of the elephant to be sure that it too has Mendelian inheritance. Thus, we do have certainty in genetics, but at the same time there are many exceptions to Mendelian inheritance in various biological adaptations to specific situations, where an alternative form of inheritance is beneficial. No matter how many such cases are documented, they in no way undermine the truth of Mendelian inheritance. How could this truth possibly be falsified?

An even stronger argument comes from molecular biology. The unravelling of the genetic code depended on a combination of theoretical and experimental studies. From an early stage it was evident that the DNA code for the sequence of amino acids in a polypeptide chain was the same in the bacterium *Escherichia coli* as in man. Since then the same code has been found in a large number of organisms. Moreover, from the open reading frame of a DNA sequence we can accurately predict the exact amino acid sequence of a protein. In most cases it would simply be superfluous science to actually determine the sequence by other, far more laborious, methods. The code is true; it is universal, and scientists do not waste their time trying to refute or falsify it. They have many other more interesting things to do. There are minor differences seen in the code (for example, between mitochondrial and chromosomal DNA), and it is not inconceivable that some new organism will be discovered that has a different code. Moreover, if there is life on planets elsewhere in the universe, the genetic code will probably have evolved along very different lines. This would not undermine the truth of the code for all known organisms on planet earth.

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Molecular biology arose after Popper had formulated his views, but much of chemistry had already been discovered. The elements exist; the periodic table exists; why should scientists believe otherwise and attempt to undermine the rock-solid foundations of a fundamental science? Of course, rare new isotopes will be discovered, and new chemical or physical properties of known elements. But the fact of the elements, and the innumerable compounds containing them, cannot be in doubt.

The problem of induction is usually illustrated by a trivial example, such as the many white swans and the single black swan. Science does not proceed simply by adding observation on observation. It proceeds by the interaction of observation, experiment, and theory. It was ''self-evident'' to the Greek philosophers that heavy objects fall to the ground more quickly than light ones. It was Galileo's experiments that not only disproved it, but also revealed the actual rates of acceleration of an object to the ground. His experiments predict that in a vacuum a feather and a stone will fall at the same rate. When this experiment was done, it was not an attempt to falsify Galileo's conclusion, it was to confirm it. This, I believe, is the key to the issue.

A theory makes a prediction. To falsify the theory the prediction must be shown to be wrong; to confirm it, the prediction must be correct. *The actual experiment, to falsify or confirm, is one and the same.* Another example will emphasize the point. Einstein's theory of relativity predicted that light would bend under the influence of gravity. When the experiment was done in 1919, the prediction was confirmed. Had it been found that the light did not bend, the theory would have been falsified. Testing a theory or trying to falsify it depends on the same experiment. Thus, when Popper discusses the importance of attempts to falsify laws or theories, he is at the same time discussing attempts to confirm them. At worst, this is a matter of semantics. Popper may well be a great philosopher,[1,3] but there is much he did not understand about the way scientists operate and the way science advances (see also Ref. 4). There is plenty of room for a more realistic, because more inclusive, philosophy of science than his.

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