Popper's Views on Natural and Social Science
by Colin Simkin

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INTRODUCTION

There is no more to science than its method, and there is no more to its method than Popper has said.

Hermann Bondi

In this book I try to give a straightforward, connected and up-to-date account of Sir Karl Popper's leading ideas about scientific method, paying special attention to their relevance to social theory. That emphasis is natural for one who is an economist rather than a philosopher.

My reason for writing it arises from a conviction that his original ideas are still not widely understood, still less properly appreciated, in spite of his presentations of them, over almost six decades, in many articles and books that are remarkable for vigour and clarity of writing. One might expect that his fellow philosophers would have read them properly but that is seldom the case, as becomes evident from reading his 'Replies to My Critics' in *The Philosophy of Karl Popper*; see, for example, his remarks on 'the Popper legend'. I share the impression of Bartley[1] and Medawar[2] that opinions about Popper's methodology have too often been formed not so much from his own writings as from incomplete and partial expositions of his ideas by critics or revisionists[3].

There has been neglect rather than misunderstanding of Popper's work by natural scientists, although he has been primarily interested in the growth of scientific knowledge in physics and biology. Bartley laments the lack of fruitful dialogue between Popper and physicists, notwithstanding some notable exceptions, which include Einstein, Schrödinger, Bondi and Margenau.[4] Popper has had more luck with biologists, including the physiologist Eccles and the medical scientist Medawar, both Nobel prize winners, the biochemist Wächtershäuser, and the psychologist Campbell. His general contribution to scientific thinking, moreover, has been acknowledged by election to the Royal Society, as well as to a number of foreign academies of science, and by the award of prestigious international prizes.

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[1] Paul Levinson (*editor*), *In Pursuit of Truth*, pp. 268–75. See also similar remarks by I.C. Jarvie, idem, pp. 100–103.

[2] *Memoirs of a Thinking Radish*, pp. 114–15.

[3] e.g. Ayer, Feyerabend, Harré, Kuhn, Lakatos or Williams.

[4] *Philosophia*, 1978, p. 677.

Nor have his ideas been adequately appreciated or understood by social theorists. His main concern, admittedly, has been with physics and biology, and he has confessed that the only social science which had ever interested him was economics. But his general work on methodology has considerable relevance to the problems of social analysis, and he has written two important books which deal exclusively with social science. *The Open Society and Its Enemies* was first published in 1945 and *The Poverty of Historicism* in 1957, following its appearance as three articles in *Economica*, 1944–45. A few articles bearing on social science were published later, the last in 1967, after which he appears to have lost interest in its problems.

Popper's first book, the *Logik der Forschung*, had appeared in 1935 and immediately attracted a good deal of attention, so that he received, and accepted, foreign invitations to speak about it. A few economists also read it. Terence Hutchison did while studying at Bonn, and used it for his own first book, *The Significance and Basic Postulates of Economic Theory* (1938). Gottfried Haberler also read it, at Harvard, and recommended it to Hayek, who then invited Popper to address his seminar at the London School of Economics. There he spoke formally about methodological problems in social science. This lecture was developed into *The Poverty of Historicism* in New Zealand, where Popper taught from 1937 to 1945. Influenced by the *Logik* and by this lecture, Hayek wrote an important article, 'Economics and Knowledge' in *Economica* (1937), which Hutchison claimed[5], perhaps exaggeratedly, is a vital turning point in Hayek's ideas about epistemology.

In New Zealand, Popper also wrote *The Open Society*, and it was published in England shortly before his arrival at the LSE to take up a teaching post which he held until his retirement in 1969. This book came out a year after Hayek's *The Road to Serfdom*, and both were widely read and discussed. Independently written, they attracted attention because of different yet complementary exposures of the intellectual roots and direful consequences of totalitarian influences, powerful even after the collapse of Nazi Germany and Fascist Italy.

Social thinkers thus became aware of Popper's emphatic rejection of ideas that there are inevitable historical laws which determine social developments, which could help us to predict such developments, and which it is the task of social science to

[5] *The Politics and Philosophy of Economics*, 1981, p. 215.

discover. They would also have become aware of his advocacy of 'piecemeal social engineering' as against holistic or collectivist central planning.

But his constructive attacks on historicism and collectivism were strongly resented by various Platonists, Hegelians, Marxists, sociologists of knowledge, and wholesale planners, so that there were polemical arguments and misunderstandings which have long obscured or distorted the transmission of his ideas. Similar troubles arose from his vigorous exposures of the poverty of the logical positivist and linguistic schools of philosophy, then dominant and especially in Britain.

It was not until 1959 that *The Logic of Scientific Discovery* was published as an English translation and extension of the *Logik der Forschung*. The twenty-four year delay was unfortunate in that it gave time for much indirect and garbled reporting of Popper's basic ideas among those who could not read German or obtain a copy of the now very scarce *Logik*. Still more unfortunate was an even longer delay in publishing a most important *Postscript to the Logic of Scientific Discovery*. This had been sent to a publisher in 1956, but serious eye trouble prevented Popper from completing proof reading. The galley proofs circulated among his colleagues at the LSE, who made some use of them; but the *Postscript* did not appear until Bartley published it as three volumes. *The Open Universe* and *Quantum Theory and the Schism in Physics* both appeared in 1982, and *Realism and the Aim of Science* a year later. They surpass even the *Logic* in philosophical or scientific interest, and include an exposition of his original idea about metaphysical research programmes. But they came much too late to prevent widespread acceptance of misleading versions or critiques of his thought.

Between the *Logic* and the *Postscript* Popper published three other books. *Conjectures and Refutations* (1963) and *Objective Knowledge* (1972) are collections of essays, written at various dates and containing further developments of his epistemological and methodological themes. Of particular interest to social theorists are articles in the former on tradition (Ch. 4), social prediction (Ch. 16), liberalism (Ch. 17), and humanism and reason (Ch. 20). The last chapter of *Objective Knowledge* is a 'Realist View of Logic, Physics and History'. In 1977 he collaborated with Sir John Eccles, the eminent physiologist, in writing *The Self and Its Brain*, which thoroughly explores the body-mind problem, an old puzzle in philosophy and one relevant to psychology. Finally there is a paper which Popper read to Haberler's seminar in Harvard during

1963, 'Models, Instruments and Truth', a condensation of which was prepared by a colleague, Alan Musgrave, and published later in a book of essays honouring Jacques Rueff. An English translation of this French article appears under the title of 'The Rationality Principle' in David Miller's excellent book of selections, *A Pocket Popper*. It is an illuminating and suggestive account of the kind of scientific theorizing that does not use specific causal laws.

In the last few years Popper has taken, and given addresses on, what he calls 'a new view of causality' based on his propensity theory of probability. It has led him to the metaphysical view of an indeterminate and evolving cosmos, subject generally to only 'weak causality'. These ideas about probability and indeterminacy, first developed in connection with physics, have obvious relevance to biological and social sciences, relying as they do on statistical methods.

All this provides a wide range of insights for social theorists, yet they have seldom shown much comprehension of the earlier works, as L.A. Boland has often observed[6], and they have hardly noticed the later ones. Mark Blaug, for example, in his *The Methodology of Economics*, devotes seventeen pages to a sympathetic account of Popper's views on falsification, induction and corroboration but ignores other contributions, more relevant to social theory, such as historicism, piecemeal engineering, theoretical models and metaphysical research programmes. Nor, in discussing other methodological positions, does he notice Popper's more effective criticisms of them. Blaug also makes the revealing claim[7] that although Popper has had a great influence on modern economists few of them have read him, but gained such understanding as they have of his ideas indirectly and from Milton Friedman's *Essays in Positive Economics*. If so, they have gained it from one who shows imperfect knowledge, or else limited acceptance, of Popper's methodology[8].

Bruce Caldwell's *Beyond Positivism* (1982) provides another example. He devotes more space to Popper's ideas than Blaug does, but covers no more of them. His understanding of them is not enough to stop him from advocating a confused 'methodological pluralism' that denies the objectivity of economic analysis. Neither does his discussion of Kuhn and Lakatos notice Popper's

[6] Particularly in *The Foundations of Economic Methodology*, 1982.
[7] In his well-regarded *Economic Theory in Retrospect*, (1978), p. 714.
[8] See Popper's *Conjectures and Refutations*, p. 245, for a clear denunciation of Friedman's instrumentalist methodology.

criticisms of their arguments, nor recognize that Lakatos' 'scientific research programmes' are a distorted derivation from Popper's metaphysical research programmes. But then his extensive bibliography did not list *The Philosophy of Karl Popper*, which he showed no sign of having read.[9]

Not that these two examples are by any means the worst. They are given only to illustrate the need for a better and fuller explanation of Popper's ideas to social scientists. A further reason for the need is that these ideas and their developments are spread over a range of writings separated by wide time intervals, and are sometimes partly obscured by distracting polemical or historical material.

It has seemed worthwhile, therefore, to attempt bringing them together in a systematic way and as simply as accuracy permits. Some attention is paid to predecessors who had similar ideas, or who influenced Popper's thinking, positively or negatively. Part One offers an account of his writings on general scientific method, concluding with a fuller account of his pioneering work on evolutionary epistemology, his view of indeterminism, and his important critique of quantum theory which has been the major influence on his views about probability and indeterminism.

Part Two covers what he has written about the application of his general methodology to social theory, and about the distinctive problems of analyzing social phenomena. It pays more attention to anticipations and criticisms of Popper's ideas, although still trying not to let their discussion become unduly distracting. The penultimate section considers criticisms that economists have made of Popper's ideas in a recent seminar which was held exclusively for that purpose, and it concludes with my own evaluation of what economists may learn from Popper. Two appendices have been added about the genesis of *The Open Society* and about the relation between his and Hayek's views on 'piecemeal social engineering'; the first is an article which I wrote for the Australian quarterly, *Quadrant*, and the second is a shortened version of a paper given to the Christchurch Meeting of the Mont Pelerin Society in 1989 and later also published in *Quadrant*.

[9] Since then he appears to have read it as it appears in the bibliography to his article 'Clarifying Popper', which was published in the *Journal of Economic Literature* in March 1991. In this article he claims that, following the Nafplion conference sponsored by the Latsis Foundation in 1974, Friedman's instrumentalism dropped out of discussions about economic methodology and interest developed in Lakatos' scientific research programmes, especially in those aspects which most separate his thought from Popper's, Blaug playing a major role in this development (pp. 10–12).

There is also a third appendix summarising advice Popper has recently given to readers of the Russian edition of *The Open Society* (to be published in 1993).

The main results of the book might be very summarily indicated by twelve theses.

(i) Science has developed from metaphysics and has become increasingly different from it by putting theories into a logical form that allows them to be empirically tested. Yet metaphysical elements can never be completely purged from scientific theories, and some metaphysical ideas have often usefully guided scientific research.

(ii) There is neither a deductive nor an inductive path to scientific understanding of phenomena, natural or social.

(iii) The only sound way towards such an understanding is by bold conjectures about problem situations, and severe testing of these conjectures, logically and empirically.

(iv) Scientific theories are thus always provisional, liable to replacement by more informative theories which survive, for a while, rigorous tests.

(v) It is exceptional for these theories to be exact causal laws; they are rather probabilistic.

(vi) Probability is not a reflection of human ignorance but a propensity of objective situations to generate frequency distributions of events generated by those situations.

(vii) The universe is not fully deterministic but is evolving to create new situations and, in that sense, continually opens up new possibilities and so changes propensities.

(viii) Social scientists have no hope of finding historical laws of development, nor of providing any rational basis for comprehensive social planning.

(ix) They should give up attempts to emulate the physical sciences by searching for timeless causal laws.

(x) If there are social laws, these must be probabilistic, but they cannot be established by any appeal to so-called inductive probability.

(xi) Nevertheless we can reach scientific explanations of social phenomena by using models of social situations together with a very weak rationality principle which avoids the ambiguities of psychological theorising.

(xii) Such explanations can be greatly helped by piecemeal social engineering that addresses practical social problems in a scientific way.

Although conscious of personal deficiencies for attempting this kind of exposition, I have had the advantage of a close personal friendship with Karl Popper since 1939 and, particularly in more recent years, have had valuable discussions with him on most of the problems tackled here. I am also grateful to a younger friend, Rafe Champion, whose great interest in, and understanding of, Popper's work have been very helpful to me throughout the writing of this book.

1. METAPHYSICS AND SCIENCE

The gulf between Popper's way of doing philosophy and that of contemporary philosophers is as great as that between astronomy and astrology. I believe that Karl Popper is on the right track.

W.W. Bartley III

Karl Popper's strongest intellectual interests have been in cosmology and epistemology—in the study of the most general features of the whole universe as it becomes known to us, and in the study of the nature and validity of knowledge. These, indeed, were the interests of the pre-Socratic Greek philosophers living in Ionian cities whose busy trading activities brought them into touch, not only with Levantine merchants, but with Babylonian and Egyptian findings about mathematical and natural phenomena—findings which led to an accurate positional astronomy that guided the making of calendars, and so helped agriculture and navigation. These pre-Socratics, indeed, have been regarded as the first real philosophers as they ignored animistic, religious or mythical explanations of nature, such as still survive in our legal system's reference to 'acts of God', and in newspapers' astrological predictions for those born under certain planetary 'influences'. They offered, instead, disinterested arguments that were based solely on objective experience. Their daringly imaginative speculations about the cosmos and life thus pointed the way to scientific thinking, although they gave no laws for predicting future events and so fell short of modern scientific standards. Nevertheless they foreshadowed some of the ideas of Newton, Dalton and Darwin[1], and Popper has admired the 'simple straightforward

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[1] For example, Anaximander's idea that the earth is suspended in space because he speculated that it was equidistant from celestial bodies which whirled in circles around it; Democritus' view of endless change from the aggregation and disaggregation of infinite, indivisible and indestructible atoms; and Anaximander's conclusion that man must have descended from fish through animals because his long infancy would not have allowed survival otherwise.

Tyndall, writing in 1896, said 'the principles enunciated by Democritus reveal his uncompromising antagonism to those who deduced the phenomena of nature from the caprices of the gods. They are briefly these: 1. From nothing comes nothing. Nothing that exists can be destroyed. All changes are due to the combination and separation of molecules. 2. Nothing happens by chance; every occurrence has its cause, from which it follows by necessity. 3. The only existing rationality' of these pre-Socratics. He has even said that contemporary philosophy would do well to regain their progressive interest in both cosmology and a simple theory of knowledge.[2]

Cosmology and epistemology are parts of metaphysics—of attempts to explore reality, and our ways of thinking about reality, by taking some account of objective experience but always transcending its bounds. Metaphysics and science have, of course, been closely related, both historically and logically. As knowledge grew, one science after another split off from metaphysics, first astronomy and mechanics then, chemistry, geology, biology, medicine and psychology, leaving philosophy with the task of combining scientific results with cosmological speculation in the hope of obtaining a coherent intellectual framework for understanding the universe and for further research into its mysteries. But many philosophers lost interest in the task during this century owing to difficulties of non-specialists in following the abstract technicalities of relativity theory and quantum mechanics which are far removed from commonsense, the attractions of logical positivism which purposely turned its back on metaphysics or, a bit later, absorption with linguistic philosophies which show little concern with science. Others have adhered to some form of a Marxism which ceased, after Marx's death, to be scientific by becoming a closed system which, by various stratagems, was made immune to strong evidence against its theories[3], such as the labour theory of value and the law of increasing misery. Hence Popper's plea for a return to the problems discovered by the pre-Socratics, and one reason for Bartley's statement in the quotation that heads this section.

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things are the atoms and empty space; all else is mere opinion. 4. The atoms are infinite in number and infinitely various in form; they strike together, and the lateral motions and whirlings which thus arise are the beginnings of worlds. 5. The varieties of all things depend upon the varieties of their atoms in number, size, and aggregation. 6. The soul consists of fine, smooth, round atoms, like those of fire. These are the most mobile of all: they interpenetrate the whole body, and in their motions the phenomena of life arise.

'The first five propositions are a fair general statement of the atomic philosophy, as now held.' *Fragments of Science*, Vol II, (1896), p. 136.

Motz and Weaver also remark that 'In a sense, particle physics began with the speculations of Democritus as to the nature of matter and his atomic theory'. *The Story of Physics* (1989), p. 329.

C.I. Davern, in his introduction to *Genetics: Readings from Scientific American* (1981), notes that the Pre-Socratics interest in change and constancy are also the pre-occupations of genetics, as were evolution and its mechanism of natural selection.

[2] See *Conjectures and Refutations*, Ch. 5.

[3] See P.A. Schilpp, editor, *The Philosophy of Karl Popper*, (1974), p. 985.

Because Popper has always recognized the importance of metaphysical ideas in underlying and shaping scientific thought and research he found it necessary to consider Kant's problem of distinguishing science from metaphysics. The problem arose from Hume's dictum that, because a metaphysical theory is devoid of mathematical reasoning or of experimental reasoning about fact, 'it can contain nothing but sophistry and confusion'.[4] Kant, however, held that there was another class of meaningful statements or judgements than the analytic and empirical ones stressed by Hume. This was the class of *synthetic a priori* statements which are neither tautological nor dependent on sense experience, in particular, the presuppositions of traditional logic, arithmetic, Euclidean geometry and Newtonian physics. They included what Kant called the 'principle of universal causation'. All, he held, are involved in our thinking about the world, and especially in scientific thinking.

Philosophers found difficulties with this idea, and relativity theory destroyed it by showing that neither the presuppositions of Euclidean geometry nor those of Newtonian physics were necessary or valid categories of thought. The Logical Positivists of the Vienna Circle thus took up Hume's view about the uselessness of metaphysics, being greatly influenced by Wittgenstein's argument that every meaningful statement must be logically reducible to elementary statements about experience. Popper objected that this view coincided with induction, and would make science itself meaningless because no scientific theory could itself be logically reduced to elementary statements about experience.[5] For such statements refer to some particular events while a scientific theory covers all possible events within its field and, as Hume himself had pointed out, we cannot logically derive a general statement from any number of particular statements. (More is said about this in § 4.) Popper also saw Kant's principle of universal causation as indistinguishable from induction, and thought that Kant's attempts to establish it as *a priori* valid were unsuccessful. Statistical and quantum mechanics had shaken faith in the determinism that was required by this principle.

Rejecting, then, the prevalent idea that scientific statements differ from metaphysical statements in being 'meaningful' because they are based on induction, and denying that metaphysical statements are always meaningless, Popper proposed acceptance

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[4] Final sentence of *An Enquiry Concerning Human Understanding*.

[5] *The Logic of Scientific Discovery* (1959), p. 36.

of a *demarcation criterion*; scientific statements are to be distinguished from metaphysical statements by having a logical form that makes it possible for them to be refuted by 'experience'[6]. They must, that is, be *falsifiable* in the sense of having logical consequences which *could be* contradicted by factual statements about experiments or observations. This had become clear to Popper after hearing a lecture by Einstein in which he listed some possible experimental results that could falsify his new theory of relativity.

Falsification of a theory occurs if scientists come to accept the validity of statements which contradict some of its consequences. While falsifiability is a purely *logical* requirement, falsification is always problematic because there can never be a logical compulsion to accept the truth of a falsifying statement[7]; it can be questioned or even denied without involving any purely logical error. Thus flat-earthers dismiss contradicting evidence that the earth is spheroid, and creationists evidence that species have evolved. A more serious example is the various attempts to save the wave-theory of light from exposures of its difficulties by endowing a hypothetical ether, through which light was supposed to be propogated, with more and more complex features.

J. Bronowski has raised another difficulty.[8] A sample test of a probabilistic theory—one that predicts several possible outcomes from an experiment or trial—may give results that do not clearly contradict the predictions. The results may be very improbable but they may not be impossible. To meet this difficulty Popper had proposed the methodological rule that 'extreme improbabilities have to be neglected'; so that if the combined results of a series of tests is highly improbable we should take this as a falsification of the theory. Bronowski thought this would be sensible but makes the test of falsification arbitrary by leaving open how extreme the improbability has to be before a theory is to be regarded as falsified. He saw a corresponding difficulty in deciding whether a theory had survived falsification, quoting the Neyman-Pearson finding in mathematical statistics that we cannot escape either errors of rejection in falsification or errors of acceptance in verification.

In his reply, Popper reiterated that no empirical statement,

[6] idem, p. 41 and Appendix i*.

[7] See *Realism and the Aim of Science*, 1983, pp. xix–xxi.

[8] *The Philosophy of Karl Popper*, p. 616. A similar criticism has been made more extensively by the economist G.C. Archibald in 'Refutation or Comparison?', *British Journal for the Philosophy of Science*, 1966.

probabilistic or otherwise, could ever be proved so that verification is always impossible. (See § 4 below.) As for falsification, he had previously discussed that in *The Logic of Scientific Discovery*. There he argued that although probability statements are non-falsifiable they can be used as falsifiable statements by applying some kind of methodological rule which draws a line between permissible and impermissible sample results according to the precision of our measurements. In that way non-reproducible effects are excluded and the rule 'requires not a mere rough agreement but the best possible one for . . . all *reproducible effects*'.[9] There is, that is, need for significance levels in testing probabilistic theories and critical scrutiny of these levels. Without them, probabilistic theories would be metaphysical, lacking empirical content, and there could be little hope of scientific progress.

Popper, accordingly, has always recognized a certain vagueness in his demarcation criterion[10] because there is no clear-cut division between science and metaphysics. Yet he thinks that it is sharp enough to distinguish many, if not most, scientific theories from the speculations of metaphysics or pseudo-science. These speculations could become scientific if ways were found of bringing them to the test of experience, and the practical importance of his criterion is that it indicates how scientific knowledge grows by searching for better tests of theories and by making them more informative.

There are plenty of instances where a scientific consensus has been reached about statements that refute a theory, or theoretical system, and where the refutation was followed by successful work in developing a better theory or system. Popper's list of twenty examples, 'chosen almost at random', ranges from Galileo's refutation of Aristotle's theory of motion, followed by Newton's theory of forces, to the refutation of the Einstein-Weyl electrical theory of matter by the discovery of the neutron, followed by Yukawa's theory of nuclear forces[11]. An example from economics would be the refutation of Say's law that supply always creates its own demand and its replacement by Keynes' principle that supply depends upon effective demand. Popper's criterion is thus a useful one even if it is not always clear-cut in particular cases.

There are, then, metaphysical theories and scientific theories.

[9] *The Logic of Scientific Discovery*, p. 205. This view, an apparent concession to conventionalism (see § 5 below), is buttressed by a somewhat complex logical argument about the form of probability statements.

[10] See *The Philosophy of Karl Popper*, Part III, §§ 5–8.

[11] *Realism and the Aim of Science*, pp. xxvi–xxx.

The former comprise a wide class of arguments, including religious myths, theology, and untestable assertions or speculations about natural, psychological and social phenomena. Examples of the former would be the cosmology of the Book of Genesis, the Calvinist doctrine of predestination, the ethical theory of natural rights, Freudian psychoanalysis, and Marxist theory. Even the valuable Darwinian theory of natural selection is regarded as metaphysical because it is ultimately untestable.[12] For this theory is an historical hypothesis about the ancestry of life forms on our planet, a particular statement about a unique development rather than a universal statement, even if this development has proceeded in accordance with physical, chemical and biological laws. There can, by definition, be no generalizations about unique facts or processes.

We should recognize, nevertheless, that demarcation of theories according to testability is not the same thing as demarcation according to their intellectual worth. The testable theory that alcohol causes drunkenness is less valuable, from the standpoint of growth of knowledge, than is Darwinism conceived as a metaphysical research programme. Similarly, Popper's views on indetermininism and realism, both as he says metaphysical, have guided his own explorations of statistical and quantum mechanics.

Besides metaphysical and scientific theories there are logic and mathematics, misleadingly called 'deductive sciences' because, being non-empirical and tautological, they are beyond scientific testing. They are the only fields in which absolutely certain truth can ever be reached, but empirically empty truth saying nothing about reality[13]. Clifford had drawn an influential distinction between mathematics and its applications, maintaining that a geometry as a whole can be said to be correct or incorrect only when it is 'applied'; and ceases to be mathematics when it becomes open to empirical tests.[14] Or, as Einstein put it: 'In so far as the statements of geometry speak about reality, they are not certain, and in so far as they are certain, they do not speak about reality'.[15] Yet all theories, metaphysical or scientific, must conform to the laws of logic if they are to avoid nonsensical statements,

[12] *The Philosophy of Karl Popper*, pp. 136 ff and 984–85; *The Poverty of Historicism*, § 27.

[13] *The Open Society and Its Enemies*, (1966), Vol II, p. 13.

[14] See John Passmore, *A Hundred Years of Philosophy* (1966), p. 323.

[15] Quoted in *The Logic of Scientific Discovery*, p. 314 fn.

and most sciences find some mathematics indispensable for formulating and testing their theories.

Popper distinguishes different aspects of the reality which these theories try to explain by speaking of three 'worlds'.[16] World 1 comprises physical things, states or processes; it has been the earliest and main concern of philosophical cosmology and later of the natural sciences. World 2 comprises mental states and behavioural dispositions; it has always been the main concern of epistemology and, of course, of the psychological sciences which sprang from epistemology.

Nearly all epistemology, ancient and modern, has failed to distinguish clearly between subjective and objective knowledge, and most of it has concentrated on subjective knowledge, and so on World 2. Descartes, for example, took knowledge to be an activity that requires a knowing subject, and the British Empiricists, beginning with Locke and Berkeley, took sense experiences to be the basis of all our knowledge. Others, such as Plato, Aristotle and Kant, found an important role for intuition, the ability of the mind to grasp basic aspects of reality.

Popper's epistemology is very different. It focuses on his World 3 of objective contents of thought, 'the content of scientific and poetic thoughts and great works of art'. A book, for example, is itself a physical object and so part of World 1; what puts it into World 3 is its content, which remains the same through various printings and editions. As a World 3 object the content of the book may induce some people to produce other books and thus to act upon World 1 which is a compelling argument for regarding the content as real. Even more compelling is the argument that a scientific theory can lead to great changes in World 1; for example, the theory of heat led to railways and steamships, and quantum mechanics led to the atomic and hydrogen bombs.

The innermost nucleus of this third world comprises 'problems, theories and criticisms'. Values—moral, aesthetic and intellectual—also belong to it because, like theories, they are mental products and can be objectively discussed and criticized. But they do not belong to the nucleus because they transcend and dominate it, especially the value of truth which Popper takes to be the supreme regulative principle for objective knowledge, and so for science.

All these mental products of our culture spring from, or are

[16] *Objective Knowledge*, (1972), Ch. 3.

developed by, individual minds, and in that respect they are undoubtedly subjective. But once they are published or performed they become accessible to other minds for appreciation, discussion, criticism, testing, exploitation or development. They become, that is, *intersubjective*, no longer dependent on any single mind, and that is what makes them objective. He acknowledges that this idea of a third world has some resemblance to Plato's theory of Forms or Ideas, a closer one to Bolzano's universe of statements and truth, and a closer one still to Frege's universe of the objective contents of thought[17]. (Although highly critical of Hegel, he also gave qualified support to Hegel's concept of 'objective mind', according to Bartley, when he first presented the idea of World 3 to his seminar at the LSE.)

Popper insists upon 'the reality and partial autonomy' of World 3.[18] It is an objective language, evolving in mutual interaction with the human mind, that converts our thoughts from the subjectivity of World 2 to the objectivity of World 3. In this way the contents of thought go outside ourselves to become objectively criticizable by ourselves and others, to be used or developed by them, perhaps long after we have died and so have ceased to belong to World 2. In that sense they become real, and are more real in that they can become autonomous because of unforeseen or unintended consequences of the objective contents our thoughts upon all three worlds.

Arithmetic provides a good example. Numbers, no doubt, were invented for elementary purposes of counting and measurement. But they gave rise to problems of a more abstract nature. It was found that there are prime numbers—those not expressible as a product of other prime numbers—and, further, that the occurrence of primes in an arithmetical sequence of natural numbers becomes rarer as the sequence progresses. It might be conjectured, therefore, that there is a greatest prime number but Euclid showed that this is impossible. The ancient Greeks also formulated 'the fundamental theorem of arithmetic', namely that a composite number can be expressed as a product of primes in only one way, e.g. 27 = 3x9 = 3x3x3. During the 18th and 19th centuries mathematicians spent much time in testing natural

[17] See *Objective Knowledge*, pp. 122–27 for some discussion of the ideas of these predecessors and also those of Hegel. Popper, it may be noted, recognizes the Stoics as the first to make 'the distinction between the (third world) objective logical *content* of what we are saying, and the *objects* about which we are speaking', op. cit. p. 157.

[18] *The Open Universe*, pp. 118–22.

numbers for primeness, and Fermat thought that any number which had the form 2^x+1, where $x = 2^n$, would be prime but Euler showed that if n = 5 the number would be composite. A more successful result was the proof by Hadamard that if p(n) is the number of primes less than or equal to integer n, then the limiting value of $p(n)/(n/\log_e n) = 1$. Results such as this were far from the minds of those who first used numbers, and came from long study of the objective properties of number systems. They also show the reality of number systems in reacting upon minds in World 2 as mathematicians discovered and tried to solve problems in these systems. Numerous examples could be cited in empirical science; one would be Mendeleyef's proposal of a table to display the periodicity of the properties of chemical elements by listing them according to their atomic weights; this stimulated the search for new elements to fill vacant places in his table.

Any scientific theory, similarly, has logical consequences that often greatly exceed those of which scientists are currently aware. Some of these unknown consequences may, for all we know, turn out to be inconsistent with earlier or later factual observations, thus requiring revision of the theory or its replacement by a better one. That is a powerful reason for holding, with Popper, that all scientific theories, no matter how well they seem to be founded, must be held provisionally and tentatively, never taken as giving us certain truth.

For these reasons Popper regards epistemology as 'the theory of scientific knowledge'[19], and holds that 'all science is cosmology'[20]. Traditional epistemology, on his view, is largely irrelevant to the study of scientific knowledge because it concentrates on problems of subjective knowledge, problems which are very much the concern of psychology. What is relevant to objective knowledge and its growth is not psychology but the study of scientific problems and problem situations, of scientific theories and discussions, of critical arguments about theories and tests, the role played by evidence in arguments, and so that of scientific journals and books. In brief, 'the study of a largely *autonomous* third world of objective knowledge is of decisive importance for epistemology'[21].

World 2, however, is seen to be important as the causal link between the other two worlds[22]. It involves perceptions of the

[19] *Objective Knowledge*; p. 108.

[20] *The Logic of Scientific Discovery*, p. 15.

[21] *Objective Knowledge*, p. 111.

[22] idem, pp. 153–56.

physical phenomena of World 1, and creates the mental constructs of World 3 which relate to World 1 and to World 2 itself. And it is through the behavioural influences from World 2 that we use the theories of World 3 to affect World 1, often profoundly as, in their different ways, economic historians and environmentalists have recognized.

How do social phenomena fit into this tripartite division of reality? Social theories and social rules, such as a legal framework or a system of markets, obviously belong to World 3, and social agents to both Worlds 1 and 2. And these agents affect World 1 because it includes not only natural phenomena, such as climate and natural resources, but human constructs, such as transport networks or capital equipment. A social situation thus involves some elements of all three of Popper's 'worlds', and—it is important to stress—all have to be treated *objectively*. We shall repeatedly see that Popper stresses objectivity in regard to observation, explanation and criticism as decisive for scientific progress; in particular, he would have subjectivism purged from probability theory, quantum physics, and all explanations of social phenomena.

2. GROWTH OF KNOWLEDGE

The central problem of epistemology has always been and still is the problem of the growth of knowledge. And the growth of knowledge can be studied best by studying the growth of scientific knowledge.

Karl Popper

Popper early came to see (while studying educational psychology at a teachers' training institute) that the growth of knowledge had to relate primarily to objective knowledge, because of the 'priority of the study of logic over the study of subjective thought processes'.[1] He came to this view by discerning two mistakes in logic which had led to mistakes in psychology. The first mistake was made by Külpe who, through confusing logical and material implication, held that arguments were complex judgements and thus denied a difference between arguing and judging. The second mistake was made by his teacher, Bühler, who had not seen that the descriptive function of language could be distinguished from its argumentative function.

Subjective knowledge, moreover, develops as we try to deal with objective problem situations, and it throws less light upon the growth of objective knowledge than this throws upon the growth of subjective knowledge. As Popper put it: 'An objectivist epistemology which studies the third world can help to throw an immense amount of light upon the second world of subjective consciousness, especially upon the subjectivist thought processes of scientists; but the *converse is not true*.'[2]

As bodies we are part of World 1, and as minds part of World 2, but not the whole of it because Popper's theory of 'evolutionary epistemology' finds a place there for other forms of life. All organisms, he thinks, even plants, are born with certain innate dispositions and expectations arising from their biochemical make up. These expectations, which can be regarded as uncertain conjectures, give organisms preferences for action in the problem situations that they encounter, and success in coping with them has determined the survival of species. The most urgent problems arise from the basic needs to satisfy hunger and to

[1] *The Philosophy of Karl Popper*, p. 61.
[2] *Objective Knowledge*, p. 112.

procreate, and attempts to solve them have led, somehow or other, to such remarkable achievements as the spinning of spiders' webs, the building of beavers' dams and the remarkable navigational skills of salmon and migratory birds.

He holds, indeed, that evolutionary theory links epistemology with cosmology because it 'links knowledge, and with it ourselves, with the cosmos; and so the problem of knowledge becomes a problem of cosmology.'[3] Knowledge, he conjectures, is as old as life[4] and it has developed with life's environment, which itself has been changed by biological evolution, notably oxygenation of the atmosphere by green plants or the evolution of those grasses and cereals which provide nutriment for animals and men.

Some knowledge is undoubtedly innate, depending on biological factors, as is shown perhaps by the migration of newly hatched turtles to the sea, or by newly born animals suckling their mothers' teats. But most knowledge becomes objective and grows through attempts to solve problems, more practical as in the case of using bows and arrows to hunt game, or more theoretical as in the case of measuring time. Human attempts at solving problems have been enormously helped by the development and use of language to construct theories about relations between phenomena in World 1 or World 2, and these theories have both a subjective and an objective aspect.

The subjective aspect relates to the mental states and processes of the problem solver,—how he acquires knowledge, the scope of this knowledge, and how reliable he can take it to be. That has been almost the exclusive concern of traditional epistemology. Rationalists, from Plato to Leibnitz, have held that ideas of reason, intrinsic to the mind, are the only secure basis for knowledge, and on that basis have tried to build a deductive epistemology. Most empiricists have had a very different epistemology, 'materialist' as against 'idealist', but one that is also subjective because it gives primacy to sense experiences, particularly

[3] *A World of Propensities*, p. 39.

[4] He cites the great biologist, H.S. Jennings who, as long ago as 1906, was able to attribute aims and intentions to unicellular organisms because he saw symptoms of activity and initiative in their behaviour; *Objective Knowledge*, p. 183 and *The Self and Its Brain*, p. 29.

Motz and Weaver, in the preface to their book, *The Story of Physics* (1989), make these remarks. 'Every living thing in the universe, even a single cell, has the knowledge necessary for life, which is far beyond anything we know consciously. Our eyes (or the cells in our eyes) know far more about optics than we do, and if we had to tell the organs in our bodies how to operate,we should quickly die.' They distinguish between knowledge *per se* and science, which they take to be active pursuit of conscious knowledge by a group of people (scientists).

those of an observational character.[5] Influential theorists, moreover, have tried to make probability depend upon subjective ignorance about events[6], a view adopted by those now called 'Bayesians'. Physics, itself, has been invaded by subjectivism with widespread acceptance of subjective interpretations of probability in quantum theory, and of Szilard's view that the cost of subjective information is an increase of physical entropy.[7]

Popper is opposed to all such views. He does not believe that intuition is an infallible or certain guide to truth, nor that scientific knowledge, as distinct from mathematical knowledge, can grow by a process of pure deduction. Nor does he believe that there is anything direct, immediate or certain in our sense experiences. Learning about ourselves and the world around us 'is all decoding, or interpretation', and that does not function faultlessly, especially during a learning process or if unusual situations arise.[8] We have always, that is, to interpret our sense experiences in the light of what we have already learned, and if such decoding seems to be direct and unconscious that is because we have already learnt enough about ourselves and our environment to make this possible. He takes, accordingly, a fundamentally different view about the problem of knowledge from these influential predecessors, whom he calls 'belief philosophers'. They were searching for justification to make cognitive beliefs secure, and thought that they could find it in clear intuitions or in direct sense experiences. In his view, they were mistaken, and the epistemological problem is quite different. 'Security and justification of claims to knowledge are not my problem', he says. 'Instead my problem is the growth of knowledge'—objective knowledge. Here, as in other fields, there is a clash between progress and security.

The objective aspect of knowledge relates to the content of theories and to their structural relations or interrelations. There may, of course, be interactions or feedbacks between subjective and objective aspects of problem solving; Kepler for example, made many mathematical trials before reaching a satisfactory explanation for planetary motions. But it is important to recognize that, once a theory has been created and expressed, it be-

[5] Popper accuses the classical epistemology as being pre-Darwinian because it fails to see that supposedly given sense data are, in fact, adaptive reactions 'impregnated with conjectural expectations'. *Objective Knowledge*, p. 145.

[6] See § 6.

[7] For Popper's critique of this entropy argument see *Quantum Theory and the Schism in Physics*, § 5.

[8] *Objective Knowledge*, p. 36.

comes part of objective knowledge and may contribute to its growth, as in the case of Lavoisier's theory of combustion which gave rise to modern chemistry. It is Popper's insistence on this objective character of knowledge that makes his epistemology 'without a knowing subject'—knowledge that is independent of anyone's belief or claim to know—diverge most strongly from the traditional epistemology which still bedevils discussions of scientific method[9].

Scientific knowledge is objective knowledge *par excellence*, so that Popper takes it to be the clearest case for studying growth of knowledge. The starting point is always a *problem*, one which arises as we try to understand or use the world better by finding a satisfactory explanation for some group of phenomena that interests us. A theory about these phenomena is proposed tentatively, and it is then tested in various ways. The testing may well lead to the discovery, often unexpected, of errors, new facts or other difficulties in the tentative explanation. A different problem situation then arises, and is dealt with, sooner or later, by proposing a modification to the original theory or else a new one. There will then be further testing, discovery of new difficulties, the conjecture of still another theory to deal with them, and so the process goes on.

He depicts it in a simple way:

$$P1 \rightarrow TT \rightarrow EE \rightarrow P2$$

Here P is a problem, TT a tentative theory, and EE error elimination through testing; – testing the theory's logical consistency, its explanatory power as against that of rival theories (particularly in regard to novel applications), and its correspondence with fact. Not only can the process lead to new and better theories, it also promotes the discovery of new facts and new problems. Knowledge, accordingly, is doubly enlarged.

That is how Popper sees the growth of objective knowledge, and his theory of evolutionary epistemology generalizes his views to cover learning by all forms of life from primitive amoeba to quantum physicists. It is a theory which stresses *activity in solving problems*, practical or theoretical, by a fundamental process of trial and error. This process involves proceeding from old to new problems by means of conjectures and refutations so that we come to understand more about them. Our knowledge, at any time, consists of those conjectures or theories which have best

[9] idem, Ch. 3.

survived experience or deliberate testing[10].

Popper believes that this process of learning by trial and error applies to animal knowledge, to pre-scientific knowledge, ancient or modern, and to scientific knowledge. What distinguishes scientific knowledge is the careful formulation of testable theories that attempt ever more general explanations of a highly informative kind, and the systematic criticism and testing of such theories. His examples of this process in science are mostly taken from physics, and a few may be noted here by way of illustration. The work of Faraday and Maxwell on electromagnetic fields of force overthrew Newton's basic concept of central forces and led to new theories of matter. Thomson's discovery of the electron refuted Dalton's theory of indivisible atoms and introduced the idea of structure as well as electricity into the atom. Rutherford's overthrow of Thomson's vortex model of the atom led to the quantum mechanics developed by Heisenberg, Born, de Broglie, Schrödinger and Dirac[11]. Lenard's experiments on photo-electricity contradicted Maxwell's theory of electromagnetism and led, first to Einstein's theory of photons, and later to particle-wave dualism[12]. Most impressive of all, Einstein's general theory of relativity displaced Newton's theory of gravitation and changed scientific concepts of both time and space.

There are no such clear examples in economics, although at least three changes in economic thinking have been called revolutions. Mercantilist theories that national wealth depended upon the available supply of bullion, and that governments should regulate trade and industry so as to increase this supply, were overthrown by the 'classical' economics of Adam Smith and David Ricardo. They, too, were concerned with national wealth but based their analyses upon a labour theory of value. This theory proved to have weaknesses, and so gave way to marginal utility theories which stressed the functioning of markets and neglected national wealth or income. Then came the Keynesian 'revolution' which strongly revived interest in national income and employment with the aid of new aggregative concepts—consumption, saving, investment, liquidity preference, etc.—and postulated interconnected relations between them. More recently that kind of theory has been sharply challenged by a new monetarism which has itself been greatly changed by a still newer theory of 'rational expectations'.

[10] idem, Ch. 7.
[11] *Realism and the Aim of Science*, pp. xxvi–xxx.
[12] idem, p. xxix.

But, as Hutchison points out[13], revolutions in economics do not spread so rapidly, nor achieve so high a degree of consensus, as they do in physics. Older theories are seldom completely discarded, and may even be vigorously revived when weaknesses appear in their successor theories. At the present time, indeed, economics is far from having reached any consensus as there is widespread dissatisfaction with leading theories and a search, as yet dubiously successful, for better ones. All this points to the difficulties of finding and applying adequate scientific analysis of social phenomena, as will be discussed in Part Two.

[13] *On revolutions and progress in economic knowledge*, (1978), pp. 72–87.

EE INSERTED

3. DEDUCTIVE KNOWLEDGE

I hoped sooner or later to arrive at a perfected mathematics which should leave no room for doubts, and bit by bit to extend the sphere of certainty from mathematics to other sciences.

Bertrand Russell

Before continuing this discussion of the empirical sciences it is as well to consider what Popper has to say about the 'deductive sciences' of logic and mathematics. Although not themselves empirical, they have had much to do with the development of the natural sciences. As the 19th century British physicist, Tyndall, remarked : 'Mathematics and Physics have long been accustomed to coalesce. . . . Indeed, without mathematics, expressed or implied, our knowledge of physical science would be both friable and incomplete.'[1] Some philosophers, moreover, from Pythagoras to Russell, have seen in mathematics a basic aspect of reality or at least a model for scientific method.

Theorems in logic and its derivative, mathematics, are conclusions inferred from initial premises, and are regarded as validly inferred if the various steps from premises to conclusions conform to a few generally accepted rules of inference that ensure transmission of truth from premises to conclusions, and re-transmission of falsity from conclusions to premises[2]. A validly inferred conclusion may yet be false. For example, from the premises that 'only things produced by labour are valuable', and that 'land is not produced by labour', it would follow that 'land is not valuable'; a false conclusion because the first premise is false. Logic and mathematics are thus not abstractions from reality but quite independent of it although, of course, they are often needed for stating and testing empirical theories.[3]

In logic the fundamental requirement of a theory, scientific or otherwise, is that it be free from contradiction. The reason for this is that contradictory statements would, as Popper has shown, imply any other statement, whatever its truth or falsity[4]. They

[1] *Fragments of Science*, Vol. II, (1896), p. 76.
[2] *Objective Knowledge*, p. 30.
[3] Popper gives a full discussion of this problem in *Conjectures and Refutations*, and the interested reader may be referred particularly to pp. 210–12.
[4] *The Logic of Scientific Discovery*, (1959), p. 91n.

12. EVOLUTIONARY EPISTEMOLOGY

Popper's epistemology marks a major achievement: the first and only unified theory of knowledge. One single coherent process of knowledge, a problem-solving process, is seen as stretching from the earliest inklings of life to the latest advances in science and technology.

Günter Wächterhäuser

It was pointed out in § 1 that Popper's main interests have been in epistemology and cosmology, and that both are part of metaphysics. It seems appropriate to consider these interests further because his earlier views about them have undergone considerable changes—not so much revisions as bold and illuminating developments. In this section I consider his invention of what Donald Campbell has called 'evolutionary epistemology', and in § 13 his brilliant arguments for an indeterministic universe.

Although Popper had, from his youth, an interest in biology he published hardly anything about it until the 1970s. In the *Logik der Forschung* (1934) he had compared his theory of the growth of scientific knowledge by formulating and testing theories with the Darwinian process of survival of the fittest, but it was not until 1961 that he began to develop evolutionary epistemology. The occasion was his delivery of the Herbert Spencer Lecture at Oxford, an extended version of which was published in *Objective Knowledge: an Evolutionary Approach* (1972). In *The Philosophy of Karl Popper* (1974) he contributed an intellectual autobiography which had a section on Darwinism as a metaphysical research programme, and he also warmly commended Donald Campbell's contribution, 'Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes'. Further development came in *The Self and Its Brain* (1977) where he wrote on 'The Biological Approach to Human Knowledge and Intelligence' (§ 34), and on 'The Biological Function of Conscious and Intelligent Activity' (§ 36). In the same year he delivered the first Darwin Lecture in Cambridge, 'Natural Selection and the Emergence of Mind', reproduced as Chapter VI of *Evolutionary Epistemology* (1987, edited by Gerald Radnitzsky and W.W. Bartley). His latest contribution is 'Towards an Evolutionary Theory of Knowledge', published as the second part of *A World of Propensities* (1990). In developing these ideas Popper was influenced by the valuable work of Konrad Lorentz, the Austrian ethologist, and Donald Campbell, the American psychologist, with whom he had valuable interchanges.

The result has been a unification and generalization of his philosophy. This is indicated by the change in his view about the main task of epistemology; in *The Logic of Scientific Discovery* it had been stated as 'the problem of the growth of knowledge', but in *The Philosophy of Karl Popper* it is stated as 'to understand it as continuous with animal knowledge; and to understand also its discontinuity—if any—from animal knowledge'. Emphasis was thus shifted from the top end of the evolutionary scale, scientific knowledge, to the whole of it, and knowledge widened to include cognitive structures of men and animals. It has dealt a further blow to the naive belief of the British empiricists and their followers that human sense experience is the foundation for justifiable knowledge.

The basis of this theory of evolutionary epistemology is a very wide concept of knowledge as adaptation to a partly unknown environment, and hence an uncertain adaptation. Some adaptation is seen as necessary for all organisms, if they are to survive, and as having begun with the pre-cellular life that was formed about 3.8 million years ago. It continued with the emergence of unicellular bacteria which rapidly spread over the earth, adapting to many different environmental conditions. Then, with the invention of photosynthesis as a source of food, and the development of other biochemical processes of increasing complexity, there evolved all forms of plant and animal life, many of which have disappeared. Each step in the evolution of life has been one of trial and error; if erroneous, it led either to the atrophy of organs which turned out to be useless or else to destruction of the species.

A key concept in this interpretation is homology, meaning a common evolutionary origin of cells or organs as indicated by fundamental similarities of structure, position or function between different organisms. Our eyes, for example, are homologous with those of most animals or fish, and they can all be traced back to a bacterium which, as Wächterhäuser has shown,[1] 'invented' a sense organ that was both sensitive to light and able to control the bacterium's movement so that it could take advantage of photosynthesis for food and yet avoid life-threatening

[1] Chapter V in *Evolutionary Epistemology*, (1987), edited by Gerald Radnitzsky and W.W. Bartley.

ultra-violet radiation. Even at this very primitive level, life had some prior knowledge of, and expectations about, its environment.

Much further up the scale of life there are fruit trees. They have need of water, and innate expectations of finding it by pushing their roots deep into the soil. They know, too, how to grow leaves for photosynthesis, how to grow erectly, how to develop then open their blossoms in suitably warm weather, how to attract bees to pollinate the blossoms, and how to develop then shed their fruit in accordance with seasonal climatic changes. Still further up the scale, consider the domestic dog or cat which both evince a good deal of knowledge about their owner's distinctive physical appearance, habits and requirements in so far as these affect the dog or cat; e.g. sources of food and times of feeding, tolerance of indoor habitation, signs of pleasure or displeasure, times of going to or returning from work, etc.

All forms of life, then, have some knowledge of their environment including some expectations about it. But there is, of course, an important distinction between unconscious innate knowledge and conscious acquired knowledge. Bacteria and plants presumably have only unconscious knowledge, but so do our own bodies. The great majority of bodily functions work unconsciously—our lungs in oxygenating the blood, the blood in circulating nutriments processed in the digestive system to every part the body, the liver in synthesizing proteins and converting protein breakdown into urea, the kidneys in dealing with urine and balancing the body's salt and water requirements, etc. And even acquired knowledge may become unconscious through memorization; we seldom need to think about how to walk, ride a bicycle or throw a dart after we have become thoroughly familiar with such activities.

For Popper then, 'the origin and evolution of knowledge may be said to coincide with the origin and evolution of life'.[2] (Is these an echo here of Kant's synthetic *a priori* judgements?) Life can exist only if it is adapted to its environment, and this environment can change. Such adaptations are both short-term, within the life of an individual, or long-term, over a considerable period of evolution. A short-term adaptation could be the response of a tree to the advent of winter by shedding its leaves, the stampede of a herd of impala on seeing or scenting a lion, or the sexual activity of a man on acquiring a mate. A long-term adaptation could be the development of sense organs—eyes,

[2] *A World of Propensities*, p. 39.

ears, and noses to respond to short-term changes, or the evolution of fins, wings, legs, arms and hands to exploit possibilities provided by the environment.

These adaptations involve both knowledge of the environment and some expectations about it, unconscious and innate in the case of the lower organisms, partly so for the higher ones, and always hypothetical and uncertain. What characterizes this adaptation for all forms of life is a basic process of trial and error. When an organism comes into a new environment, or when its present environment changes, it tries to adapt to the new conditions. If it fails it will not survive, if it succeeds it may start a new direction of evolution.

In short-term adaptation, the ability to communicate is important. Bees have a dance which directs the workers of the hive to a source of honey; birds' calls can proclaim a territory, attract a mate or warn of danger; whales and dolphins have a rudimentary language of their own which enables them to inter-change some information about short-term aspects of their environment, and sheepdogs can be trained to respond to quite a number of commands from their shepherds.

All these are examples of language, or at least of what Bühler called the expressive, signalling, and descriptive functions of language. Popper added an argumentative function—which is characteristic of human language[3], and has made science possible. Some animal languages may have a bit of a descriptive function, the bees' dance, for example, but the argumentative function seems limited to human language. Popper sees it as 'perhaps the most powerful tool for biological adaptation that has ever emerged in the course of organic evolution'.

Both the descriptive and the argumentative function developed as a result of the very general process of trial and error. The descriptive function led to the regulative idea of truth, as correspondence with fact, and the argumentative function to the regulative idea of validity, in logical argument. Together they have had the crucial result of enabling men to think rationally and critically. That has made possible far greater 'exosomatic' development than has occurred among animals—development of tools, weapons, buildings and machines which have reinforced the descriptive and argumentative functions of human language. That has enabled us to have better adaptation to our environment, and to adapt it to our own needs and purposes. We do

[3] *Objective Knowledge*, pp. 235–38.

this largely by a trial and error procedure of conjectures or hypotheses before taking action, and if testing proves a hypothesis to be erroneous it is discarded. We thus have the possibility of letting our hypotheses die instead of ourselves before taking actions which could lead to our own deaths through faulty knowledge of the environment.[4]

There is an important distinction here between biological and cultural evolution. Eccles, in a valuable survey of 'the world of objective knowledge',[5] points out that the structures made by spiders, wasps, birds and beavers are made by creatures with relatively simple nervous systems, and that there was an immense time lag between man's development of a full-sized brain and his significant cultural achievements. These achievements came only after language began to be developed. There was the genetic potentiality to participate in culture but its realization required means of communication that go beyond the animal level and also means of recording previous cultural achievements. Popper expressed it this way. 'Our selves, the higher functions of language, and the third world have evolved and emerged together, in constant interaction . . . I deny that animals have states of full consciousness or that they have a conscious self. The self evolves together with the higher functions of language, the descriptive and argumentative functions.'

Popper thinks that Kant had anticipated the most important results of evolutionary epistemology by asserting:

(i) Most knowledge of the momentary state of our surroundings is *a posteriori*;
(ii) Such knowledge is impossible without *a priori* knowledge because unless we have an overall frame of reference we could make no sense of our sensations;
(iii) This *a priori* knowledge contains, especially, knowledge of the structure of space and time, and of causality.

Here Popper interprets *a posteriori* knowledge as that obtained from what our senses tell us about momentary changes in the environment, and a *priori* knowledge as what we have prior to

[4] See Popper's 'Natural Selection and the Emergence of Mind', Chapter VI of *Evolutionary Epistemology*, (1987), edited by Gerald Radnitzsky and W.W. Bartley. In it Popper conjectures that the behaviour of animals is not just programmed but self programmed, and he distinguishes between closed programmes, which lay down behaviour in great detail, and open programmes, which evolve by processes of natural selection. Consciousness originates in the choices made available by open programmes, and would be favoured by natural selection because of substitution of imagined trials for possibly dangerous real trials.

[5] J.C. Eccles, Ch. 10 of *The Philosophy of Karl Popper*.

sense experience—innate knowledge. But he denies that *a priori* knowledge is *a priori* valid, and he goes well beyond Kant in asserting that by far the greater part of any organism's knowledge is innate, incorporated in its biological make-up. And he holds that by far the greater part of what Kant took to be *a posteriori* knowledge is actually *a priori*. For, as Kant recognized, our senses can give us only 'yes' and 'no' answers to questions; we conceive these questions *a priori*, and also interpret the answers of our senses in the light of *a priori* preconceived ideas. That, of course, tells against the British Empiricists and others who have asserted that all knowledge comes from our senses. We must have prior knowledge if our senses are to tell us anything, and such knowledge cannot possibly result from observation; it is rather the result of evolution by trial and error.

All this leads to another basic argument against induction. We do not gain knowledge by accumulating and generalizing sense impressions. Most knowledge, in all forms of life, has the character of expectations which are necessarily hypothetical or conjectural and therefore uncertain. Nevertheless much of knowledge corresponds to objective facts and so is objectively true, otherwise life could not survive. There is thus a distinction between the truth, which is objective, and certainty, which is usually a matter of subjective feeling. This means that expectations or conjectures have to be tested, and in our case critically tested by using the descriptive and argumentative functions of our language—which itself develops as we find new problems.

Popper's arguments also tell against materialism—'the view that animals and men are electro-chemical machines'.[6] The older evolutionists regarded natural selection as an interaction between chance mutations within an organism and environmental forces which the organism did not influence. But there is a newer theory of 'organic evolution' which attributes to an organism a repertoire of behaviour, and holds that it may change its environment by adopting a new form of behaviour or, at any rate, alter the biological significance of the environment to that organism. Thus the ancestors of giraffes, by developing a preference for browsing on the higher branches of trees, created a new environment for their descendants among whom new selection pressures led to the selection of long necks. As Darwin himself recognized[7], there can be changes in an organism's 'habits' which lead to changes

[6] *The Self and Its Brain*, p. 8.

[7] *The Origin of Species*, p. 183 in the Oxford *World's Classics* edition.

in its structure as well as changes in its structure which lead to changes in its habits.

Darwin thought that the question whether habits or structure change first was 'immaterial to us', but Popper does not. Evolutionary changes that begin with new behaviour patterns give evolutionary significance to an animal's preferences and aims, showing that the mechanism of natural selection becomes more efficient when there is a bigger repertoire of behaviour patterns available to it. It also throws light upon the emergence of the human mind. 'We could say that in choosing to speak, and to take interest in speech, man has chosen to evolve his brain and his mind; that language, once created, exerted the selection pressure under which emerged the human brain and the consciousness of self'.[8]

Jacques Monod has shown that although life has appeared on earth, the prior probability of its appearance is virtually zero. For a gene requires about fifty suitable enzymes to perform its main functions of producing new enzymes and its own replication, and the probability that a gene, synthesized by chance, would find these suitable enzymes is zero. This means that we cannot give even a probabilistic explanation of the origin of life, contrary to what determinists and materialists would hold. Ernst Mayr confirmed this when he wrote that 'biologists, impressed by the inherent improbability of every step that led to the evolution of man, consider . . . the prevalence of humanoids exceedingly improbable'.[9]

Nor is it easier to give a materialist explanation of the origin of consciousness. Popper thinks the most reasonable explanation is that consciousness emerged as animals came under the pressure of natural selection and that there are different levels of consciousness, but that its emergence was unpredictable and so indeterministic[10]. The biological function of consciousness is solving problems of a non-routine kind because it is not needed for solving routine problems such as the reflex processes involved

[8] *The Self and Its Brain,* p. 13.

[9] 'Evolution', in Genetics, *Scientific American,* 1981, p. 248. It may be noted that Mayr also gives strong support to Popper's view about the importance of shifts in behaviour, which he says have been pacemakers in evolution. 'A change in behaviour, such as the selection of a new habitat or food source, sets up new selective pressures and may lead to important adaptive shifts. There is little doubt that some of the most important events in the history of life, such as the conquest of land or of the air, were initiated by shifts in behaviour.' pp. 250–51.

[10] *The Self and Its Brain,* pp. 28–29.

in vision. This role of consciousness becomes clearest where an aim or purpose can be achieved in more than one way and, after deliberation, one or more of these ways is tried out. It is especially involved in situations where a new decision is called for.[11]

[11] idem, pp. 125–26.