beings are shaped by and operate within their historical circumstances and the social and cultural institutions of which they are a part. Such institutions enable human beings to be the beings they are: it is not the case that we can transcend our own historical and social setting. The nature of humankind is thus that it is developmental or progressive. The 'new science' of history does not elevate the beliefs and concepts of any one culture to transcendental superiority: such is the error which Vico calls the 'conceit of scholars'. Nor yet is history hopelessly relative: if it were, it would not be a science. Instead, human beings have a capacity for self-understanding, and the discrimination to understand historical, social and conceptual change, which makes cross-cultural historical and social discourse possible. The fact that human beings are both active in, and can construct, history is what renders history a science superior to the natural sciences. The workings of historical and social change are not directed by God or providence: even though Vico's work incorporates a widespread use of theistic and scholastic terminology, theism is not embedded within his theories of history and society.

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Kathryn L. Plant

POPPER, Karl Raimond (1902–94)

Karl Popper was born in Vienna on 28 July 1902 and died in Croydon on 17 September 1994. He studied mathematics, physics and psychology (the latter with Karl Bühler) at the University of Vienna. He fled from the Nazis in 1937 to take a lectureship at Canterbury University, New Zealand. With HAYEK's help, Popper obtained a readership at the London School of Economics in January 1946, where he taught until his retirement in 1969. Highly esteemed for his work, he was made a fellow of the Royal Society, a fellow of the British Academy, and a Membre de l'Institute de France. He was knighted by Queen Elizabeth II in 1965.

Popper is best known for his proposed method of science: conjectures and refutations, or for short, falsificationism. Scientific knowledge grows through extravagant guesses controlled by unrestrained criticism. He developed this approach, partly through debate with the Vienna Circle, in his first book *The Two Fundamental Problems of the Theory of Knowledge* (first published in 1979) and the much shortened version of this, *The Logic of Scientific Discovery* (1934/59). He shared with the Vienna Circle an admiration for science. He also shared with them the desire to (1) explain how we do know so much in science; (2) explain how we can make our knowledge grow; and (3) ascertain how we can demarcate science from non-science, pseudo-science and metaphysics.

With regard to demarcation, Popper was concerned that two of the most influential doctrines, Freudianism and Marxism, were not open to empirical criticism, yet were both being presented as scientific. Freud's theory was fundamentally immune from criticism from the start because it could 'explain' any behaviour (even incompatible behaviours). Marx's theory began as a falsifiable theory, but was later immunized against further criticism. He wanted to contrast these types of theory with Einstein's new theories, which were self-critically presented with well-formulated possible counter-examples.

Popper had fundamental disagreements with the Vienna Circle. The Circle thought they could demarcate science by the verificationist principle, which proposes that only statements that can be verified by experience are to be counted as science; indeed, the very meaning of a statement is its method of verification. Everything else, apart from logic and mathematics, was to be counted as meaningless. The problem for verificationism was that the best examples of scientific theories consisted of universal statements ('Light always travels at c'), which cannot be verified, and there are examples of non-scientific statements (e.g., 'There is a Tyrannosaurus Rex' or 'There is a type of substance 1000 times harder than diamond') that are putatively verifiable but that one would like to exclude from science. (It is not so much that these are all false but that, if they are, you cannot get rid of them by empirical means.) Moreover, the principle of verificationism itself is not verifiable, and is therefore meaningless on its own terms.

Popper's approach was to eschew the use of a criterion of meaning and instead choose a criterion of falsifiability. What should make a statement scientific was whether it could be falsified; that is, whether there were any possible circumstances whose description would contradict it. This allowed a truly adventurous conception of science, in which a theory such as '$E = mc^2$' talks about the universal and deep structure of the world, and also enabled Popper to explain and promote the growth of science and demarcate it from other intellectual activities, such as religion or metaphysics, without denying meaning to them. In contrast to verificationism, it does not presuppose a given world structure, as it allows us to discover that no universal laws can be applied: for example, we may discover that only statistical laws stand up to our critical tests.

For Popper, science ought to be a battleground of bold conjectures that are subjected to ruthless and unending criticism, a Darwinian-like process, leading to further deeper problems. The conjectures are conceived as unjustified and unjustifiable flights of fancy. But because we want to control our theories, they must be serious attempts to solve a problem, and they must also be expressed as statements that have the logical property of being incompatible with possible reproducible observations. In *Objective Knowledge* Popper proposed the following schema:

Problem$_1$ Tentative Theory(s) Error Elimination(s) Problem$_2$

The schema applies to all life, but in the case of scientists there ought to be a deliberate attempt to foster new theories and error elimination. A problem is raised, for example 'Why are these crows black?' Alternative theories are proposed and subjected to error elimination. This then raises new problems, for example 'Why are all crows black?'

The conjectures can be either universal statements, for example 'All crows are black' or singular observation statements, for example 'There is solid water at such and such coordinates C at such and such a time and date T on Mars.' The growth of our knowledge consists in theories of greater content (preferably through greater depth and generality) either absorbing unrefuted theories of lesser content or replacing refuted theories. For example, the theory 'All birds acquire their distinctive colouring because of certain enzymes, selected within that species by evolution' would absorb the black-crow theory. A nice corollary of this proposal is that theories of greater content are also more refutable; so as our science grows it becomes more controllable. In contrast, some systems of thought, such as Freudianism or Marxism, become less and less controllable by empirical means as they are elaborated, just like old computer programmes that have no uninstall procedure.

Since ancient Greece, knowledge has been conceived as justified true belief, contrasted with merely true belief or opinion. A version of this doctrine as applied to science is called induction, made popular by Francis Bacon. For Popper, verificationism was a form of induction. David Hume argued that this method was logically fallacious. Induction held that science ought to establish a theory by collecting a great number of observations and inferring, and thereby justifying, the theory from these. But, Hume said, no matter how many black crows had been observed, some unobserved crow might be non-black. As RUSSELL (1918) has pointed out, this remains the case even if the world is finite in space and time, since the claim to have examined the whole universe is itself a universal statement. Hume pointed out that one could not even make the black-crow theory probable by collecting observations because there must always be infinitely many possible cases against a finite number of actual observations. The probability of any one of our universal theories being true is therefore zero. This became known as the problem of induction. It later emerged under another name, 'the grue paradox', a clever way of presenting (but a more restricted version of) Hume's original point. Hume also asked how any principle of induction is supposed to be justified? It could not be by induction, for this would either launch an infinite regress or prompt a dogmatic stopping point.

It was clear to Popper that there was a logical gap between experience and the statements that were supposed to follow from them in the inductivist accounts. Fries had pointed out that only statements can serve as assumptions for a logical inference, but experiences are clearly not statements. So how were any statements at all, let alone scientific theories, to be derived logically from experience? Fries had suggested that we decree that direct experience just is a final court of appeal.

Popper's response to this was to give up the quest for justified true theories and replace this with the search for simply true (or at least truth-like) theories. The goal of science was the classification of theories as true or false, not their certification as justified or supported. This decision of Popper's was reinforced by the discovery by Kurt Gödel that truth and proof are radically different even in mathematics. Popper had also adopted Alfred Tarski's theory of truth, according to which a statement describes its own conditions of truth, and is therefore definable independently of any theory of proof or justification. But if even singular statements cannot be justified, how does one successfully falsify a hypothesis? Suppose one is trying to refute the conjecture that all crows are black. One may truthfully describe the presence of, for example, a non-black crow. Having accepted this statement, one may deductively infer from it that the statement that all crows are black is false. Indeed, to avoid self-contradiction, you are obliged to reject the black crow theory. (One must be clear at this point that one has not 'proven' the black crow theory false: in a proof the assumptions are jettisoned, as in a reductio ad absurdum. But in this case, we simply 'derive' the falsity of the theory on the assumption of the observation statement.)

Many objections to Popper's proposed method were either part of Popper's original exposition or were anticipated by him and exploded. He had noted that any theory could be saved from criticism by immunizing moves: this was dealt with by the rule not to introduce auxiliary hypotheses unless they augment the falsifiability of the resulting system. He had noted that falsifying a theory is a subtle and in itself ineradicably conjectural affair – the falsifying hypothesis may require ingenious guesswork and is itself criticizable (witness the competing and changing interpretations of the various alleged observations of water on Mars). This is just one place where Popper goes beyond earlier writers who are sometimes taken as anticipating Popper, such as W. Whewell and J. von Liebig (they had confined the fallibility of science to its universal theories; Popper's method deals with fallibility in an unconfined and systematic way). It also follows from this that, for example, finding a non-black crow (refuting the theory that all crows are black) is not a confirmation of the existence of a non-black crow. It is not smuggling induction in through the backdoor. He had noted, contrary to Thomas Kuhn in *The Structure of Scientific Revolutions*, that his proposal was one of method, not a historical description of what scientists do. He had noted (though later than *The Logic of Scientific Discovery*) that even a false theory might be retained if it has a large amount of truth to it; that when all our theories are strictly false, the battle between theories might be over degrees of closeness to the truth rather than truth. He had noted that metaphysics was heavily influential in the origin of scientific theories: for example, Democritus's irrefutable theory of atoms inspired the modern falsifiable version.

One of Popper's major concerns in *The Logic of Scientific Discovery* was to explore how the use of probability in physics could be squared with falsificationism. Strictly speaking, a probability hypothesis, such as 'the probability of heads in the next 100 throws of a coin is $^1/_2$' is not falsifiable because even an arbitrarily large sequence of heads is compatible with such a ratio in an infinite sequence. This is the problem of decidability. Popper fundamentally reworked Richard von Mises's theory, in an attempt to solve both the problem of decidability and stability, while retaining the application (like von Mises's theory) to both mass statistical effects as seen in statistical mechanics and purely deterministic phenomena. Popper's solution involved the idea of quite restrictive finite sequences near the beginning of a collective.

However, Popper became unsatisfied with this interpretation of probability, and substituted the much more powerful propensity theory, in which propensities are conceived as something like force fields of variable strength constantly jostling with one another for realization ('The Propensity Interpretation of the Calculus of Probability, and Quantum Theory', 1957). The notion of propensities leads onto Popper's concern with freedom and determinism. Popper was an indeterminist and his arguments are most fully developed in *The Open Universe* (1982). Scientific or 'Laplacian' determinism asserts that it is possible (in principle) deductively to explain or predict any event, to any desired degree of precision, from appropriate laws and sufficiently precise initial conditions. But this view implied that the future is as fixed as the past and therefore excludes human freedom and the possibility of radically new things emerging in the world.

Among the host of arguments that are deployed in *The Open Universe*, Popper tries to show that prima facie deterministic theories do not imply the strong version of scientific determinism; that even the weak version is incompatible with Einstein's theory. He explores the extent to which the growth of knowledge affects our ability to predict the future, and he explores how the existence of abstract things such as theories and arguments breaks open the alleged closed character of the determinist's world. Popper replaces the clockwork deterministic worldview with one based on propensities, a world still constrained by laws, but one that is more cloud-like than Laplace would have allowed.

There is a remarkable unity in Popper's work, and this is no more evident than in the relationship between his proposed method of science and his social and political philosophy, expounded in *The Poverty of Historicism* (1944–5) and *The Open Society and its Enemies* (1945). These books are a fundamental critique of wholesale (or revolutionary, utopian) social engineering (national socialist, Marxist or otherwise), and a proposal for 'piecemeal social engineering'. Mindful of our fallibility, ignorance and the ubiquitous unintended results of our plans, Popper prescribes piecemeal reform because we can better monitor and eliminate our mistakes on the small scale. Even on the small scale Popper recommends that our institutions should be designed to look for and correct the unintended repercussions of our laws and social rules. Popper offers this as an example: 'You cannot give a man power over other men without tempting him to misuse it – a temptation which roughly increases with the amount of power wielded, and which few are capable of resisting' (*The Poverty of Historicism*, 1969, pp. 62–3).

Popper proscribes revolutionary reform because we can neither easily monitor the society-wide ramifications nor reverse our leaps. Popper's adventurism in science and conservatism in politics (in the abstract sense) issue from the same aim: to enhance our control over our fallible explorations of the unknown. Many thinkers were convinced that revolutionary change was acceptable because they could scientifically predict, as an inevitable event, the coming of the future and better society. To rebut this, Popper also attacked their confusion of historical prophecy (presented as scientific) and truly scientific prediction. A scientific prediction involves the derivation of a specific event from certain laws and initial conditions; an historical prophecy consists of the stark statement that such and such will happen because it is part of an inevitable sequence. Strictly considered, scientific laws (alone) do not assert the existence of anything (let alone inevitable sequences), but only of what cannot be. ('Light always travels at c in a vacuum' does not say that light exists, only that there is no light that travels at any other velocity.) The particular affect of laws on events only comes into effect with the occurrence of certain initial conditions.

Popper argues that the prediction of social events is severely limited by the impact on society of unforeseeable new knowledge. This argument is elaborated and refined in *The Open Universe*. Here Popper develops a purely logical argument in which it is shown that no scientific predictor – of whatever type – can possibly predict, by scientific methods, its own future results. This approach is fundamentally opposed to what Popper calls historicism, the thesis that society develops according to an inevitable set sequence of stages. Marxism is perhaps the best example of historicism with its prophecy of the inevitable coming of communism, after several stages culminating in feudalism and then capitalism. But Popper saw historicism (or 'progressivism') everywhere, infecting our theories of art, science, technology and even morality. What comes later is often presumed to be better (Ray Bradbury once said that if matches had been invented after lighters, people might have thought them superior).

The Open Society and its Enemies (1945), which Bertrand Russell described as 'a work of first class importance ...', is a detailed attack on particular examples of authoritarian and historicist thought, focusing on Plato (vol. 1), and on Marx and Hegel (vol. 2). For the old authoritarian question 'who should rule?' Popper substitutes the question 'how should we change our rulers?'. It is in this book that Popper first expounds the case for critical rationalism. Popper also explores the paradoxes of democracy, for example that democracy may allow the election of a dictator (as it did in Germany) who will eliminate democracy. We must therefore design various checks and balances and uphold the freedom of the individual if we wish to safeguard democracy.

Popper wished to champion an objective conception of knowledge, and his theory of a world of autonomous objective problems, theories and arguments was the culmination of this quest. The old conception of knowledge as justified true belief saw knowledge as a state of mind of the believer. But to Popper it mattered nothing which theories Einstein believed, but it mattered a great deal what his theory and arguments were as set down on paper. Instead of asking 'Is Einstein justified in believing $E = mc^2$?', Popper wanted to ask questions such as: 'Is $E=mc^2$ true or closer to the truth than another theory?', 'What problems is it meant to solve and how well does it solve them compared to other theories?', 'What are the potential falsifiers?', 'Do the current observational statements contradict it?', 'What other theories does it logically exclude?' All these questions can be investigated independently of Einstein's state of mind. A theory is a product of a mind, but once produced and written down or recorded in some way, it has an objective existence and a life of its own. It may surprise and frustrate us in unforeseeable and not completely fathomable ways. A theory like the natural numbers, for example, may have been invented originally simply to count sheep, but once invented it has autonomous properties that can be explored, such as the prime number sequence. It can inspire problems such as 'Do prime numbers get rarer as we ascend the sequence?' Clearly, this question cannot be answered by looking at the psychology of the inventor or user of numbers. It soon became clear to Popper that many more human products had this autonomous quality.

Popper elaborated this theory in *Objective Knowledge*. He argues that one can usefully distinguish at least three sub-realms of our world: World 1, the world of physical objects and relationships; World 2, the world of psychological states; and World 3, the world of objective products of the human mind. Plato had argued for a world of forms, which were equivalent to objective concepts. Bolzano and Frege had anticipated Popper in the distinction between the content of our thought and the psychological state in which it exists: for example, my believing that the sun will set at 7pm tonight and the content or 'proposition' that the sun will set tonight at 7pm. Popper wanted to go further than these thinkers and acknowledge the objective existence of not only theories and concepts, but also problems, arguments and logical relations. Popper included music, art and even institutions within World 3.

In the *Open Society and its Enemies* Popper expounded the case for critical rationalism. He wanted to show that rational argument, which he equated with critical discussion, is possible even outside of science, even in the absence of falsifiable theories. One could even argue the merits of metaphysical theories. But there was a lacuna in the case that Popper had presented, an element of dogmatism, which his brilliant young student, William Warren Bartley III, convinced Popper to eliminate (see *Realism and the Aim of Science*, chap. 1, sect. 2). Popper had thought that an unarguable leap of faith was necessary in the adoption of critical rationalism. But by clearly distinguishing between criticism and justification, Bartley persuaded Popper that he could generalize his critical rationalism to comprehensive critical rationalism, the thesis that all positions may be held open to criticism without any requirement for faith, a method that was safe from inconsistency, dogmatism, circularity or infinite regress. A great deal of the initial debate over Bartley's position is covered in his *Evolutionary Epistemology, Rationality, and the Sociology of Knowledge* (1987).

Popper inspired many scientists, such as the Nobel Laureates John Eccles, Peter MEDAWAR and Ilya Prigogine, and other path-breaking scientists such as David Deutsch, Frank Tipler and Günter Wächtershäuser. Popper's work left us with some important problems that have inspired a great deal of useful work. Some of the most outstanding of these problems are the theory of verisimilitude, the theory of propensities, and the theory and application of World 3.

Acknowledging the fact that we can say that in an important respect, Newton's theory is closer to the truth than Galileo's, even though both theories are false, Popper proposed a definition of closeness to the truth for two theories. However, this definition of verisimilitude was refuted by D.W. Miller ('Popper's Qualitative Theory of Verisimilitude', 1974). The demise of this first proposal has stimulated much fascinating mathematical and philosophical work, an area for new thinkers to make their mark in. Popper's propensity theory has stimulated the invention of a plethora of variants, and one of the key questions is its applicability to the single case.

Little has been done in actually applying Popper's theory of World 3 and Bartley's comprehensive critical rationalism. However, an attempt is made critically to apply both in Percival's paper on the evolution of systems of ideas (1994).

Popper's work constitutes a substantial and deep exploration of some of philosophy's important questions. He discovered and delineated new problems that will engage thinkers into the unforeseeable future.

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Ray Scott Percival

POTTER, Martha Beatrice, *see* Webb

POWELL, Betty (1922–2002)

Betty Powell was born in Bury, Lancashire on 5 May 1922 and died in Exeter. She attended elementary school, leaving at fourteen to work in a mill and later in a bookshop. After attending evening classes she won a WEA Scholarship to Manchester University, where she took her first degree. She then won a Stebbing Fellowship to do postgraduate work in London, where she was awarded a PhD in 1957 for a thesis entitled 'Self-Knowledge and Morality'. In 1960 she was appointed to a joint post at the University of Exeter as the Warden of a women's residence and as a lecturer in philosophy. She was promoted to a senior lectureship in 1974. After her retirement in 1982 she continued to work as a philosophy tutor for the Open University.

Powell was an outstanding teacher and in her few publications she proved herself an able discussant. Her paper on 'Uncharacteristic Actions' (1959) argues against the view that a person's actions are only really his if they are predictable from his character. Her *Knowledge of Actions* (1967) may be regarded as a series of discussions of topics, particularly in the philosophy of mind, which much exercised philosophers at the time. Powell is critical of those authors, such as Patrick NOWELL-SMITH, who claim that an action proper must be chosen or, such as Stuart HAMPSHIRE, that it involves a trying. Though her style shows some debt to Gilbert RYLE, she devotes a chapter to criticizing his distinction between knowing how and knowing that. The last and most substantial chapter is on 'Self-Knowledge'. It is not entirely clear how the book hangs together and to that extent James Wallace, in his ungenerous review, was right to complain of its 'obscurity'.

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