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Mario Bunge: Physicist, philosopher and defender of science[1]

Mario Bunge: Físico, filósofo y defensor de la ciencia

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Resumen

Mario Bunge nació en Argentina el último año de la Primera Guerra Mundial. Aprendió física atómica y mecánica cuántica de un refugiado austriaco que había sido estudiante de Heisenberg. Adicionalmente, aprendió en forma autodidacta filosofía moderna en un entorno que era hostil. Fue el primer filósofo de la ciencia sudamericano con formación inicial en ciencias. Sus publicaciones en física, filosofía, psicología, sociología y fundamentos de la biología son sorprendentemente numerosas, e incluyen en extenso Tratado de Filosofía en ocho volúmenes. La línea unificadora de su producción es la constante y vigorosa defensa del Iluminismo, y la crítica a los movimientos culturales y académicos que niegan o devalúan sus fundamentos: su naturalismo, la búsqueda de la verdad, la universalidad de la ciencia, la racionalidad y el respeto por los individuos. En un tiempo en que se alaba ampliamente la especialización y son reconocidos sus efectos sobre la ciencia, la filosofía de la ciencia, la investigación educativa y la enseñanza de las ciencias, es saludable ver los frutos del empeño de una persona por construir una 'gran' imagen científica y filosófica.

Abstract

Mario Bunge was born in Argentina in the final year of the First World War. He learnt atomic physics and quantum mechanics from an Austrian refugee who had been a student of Heisenberg. Additionally he taught himself modern philosophy in an environment that was a philosophical backwater. He was the first South American philosopher of science to be trained in science. His publications in physics, philosophy, psychology, sociology and the foundations of biology, are staggering in number, and include a massive 8-volume *Treatise on Philosophy*. The unifying thread of his scholarship is the constant and vigorous advancement of the Enlightenment Project, and criticism of cultural and academic movements that deny or devalue the core planks of the project: namely its naturalism, the search for truth, the universality of science, rationality, and respect for individuals. At a time when specialisation is widely decried, and its deleterious effects on science, philosophy of science, educational research and science teaching are recognised – it is salutary to see the fruits of one person's pursuit of the 'Big' scientific and philosophical picture.

1. INTRODUCTION

Willard Van Orman Quine, in his autobiography, mentions attending the 1956 South American Philosophical Congress in Santiago, Chile. The only thing about the meeting that he thought worth recording was his observation that:

> The star of the philosophical congress was Mario Bunge, an energetic and articulate young Argentinian of broad background and broad, if headlong, intellectual concerns. He seemed to feel that the burden of bringing South America up to a northern scientific and intellectual level rested on his shoulders. He intervened eloquently in the discussion of almost every paper. (Quine 1985, p.266)

The congress was held nearly fifty years ago when Bunge was in his mid-30s; he is now approaching his mid-80s with his intellectual energy in no way diminished.

The core of Bunge's scholarly life is his commitment to studying and understanding the interaction of science and philosophy; to defending the best of both; and to applying what is learnt to significant social and cultural issues. Unlike many philosophers of science, Bunge seeks a holist and coherent intellectual position whereby ontology, metaphysics, epistemology, semantics, psychology and sociology are all advanced together and are made to account to each other. He abhors epistemology that is divorced from ontology; psychology that is divorced from theories of mind; and metaphysics that is conducted without regard to science. He is both a scientific philosopher and a philosophical scientist.

2. ACADEMIC CAREER

Bunge's enrolled in 1938 as a student of physics at the University of La Plata. He says that he 'went into physics for the love of philosophy' (Bunge 2003b, p.245). His doctoral thesis was in the field of theoretical atomic and nuclear physics. His first academic position came in 1941 as a teaching assistant in experimental physics at the University of La Plata. A few years later (1947-52) he became a teaching assistant in mathematical physics at the University of Buenos Aires. In 1956 he was appointed a professor of theoretical physics at the universities of Buenos Aires and La Plata. In 1957 he won the chair of philosophy of science at the University of Buenos Aires, and a year later he resigned his physics chairs to concentrate on philosophy. However, he went back to teaching both physics and philosophy during short-term appointments in the USA (University of Pennsylvania 1960-61, University of Texas 1963, Temple University 1963-64, University of Delaware 1964-65). In 1966 he became a professor of philosophy at McGill University in Montreal, and in 1969 became Head of the university's Foundations and Philosophy of Science Unit. At McGill he has taught a dozen different philosophy courses, and is the Frothingham Professor of Logic and Metaphysics. He has also held visiting professorships in Uruguay, México, Germany, Denmark, Switzerland and Italy, and has

3. PUBLICATIONS

Bunge is the author or editor of more than 50 books – including four major books in the past five years; and 500 scientific and philosophical papers – including a number of philosophy, physics and social science papers in the past two years. His papers have appeared in major journals in the disciplines of philosophy, philosophy of science, theoretical physics, chemistry, neuroscience, cognitive science, mathematics, psychology and sociology.

In 1944 Bunge was instrumental in establishing the journal *Minerva* which was devoted to the defense of rationalism against current, Fascist-inspired, irrationalisms, and various obscurantisms prevalent in Latin American philosophical and intellectual circles. He published a number of essays and reviews in the journal during its twelve months of existence. One of which was 'Auge y fracaso de las filosofía de la naturaleza' (Bunge 1944) which argued against the then common *Naturphilosophie* movements that emerged out of both Catholic scholasticism and Continental idealisms; the paper was critical of Bergson and of Husserl.

Bunge's first English article was titled 'What is Chance?' (Bunge 1951). Here he proposed an objectivist or 'propensity' interpretation of the probability calculus. He argued that chance was a feature of the world, not just a name for our ignorance. What was randomness at one level of the organisation of material was causality at another level, and conversely. The article attracted the attention of David Bohm who invited him to visit the Institute of Physics of the Universidade de São Paulo; and Bohm utilised the linked categories of randomness and causality in his *Causality and Chance in Modern Physics* (Bohm 1957).

Among Bunge's English-language books are: *Causality: The Place of the Causal Principle in Modern Science* (1959), *Intuition and Science* (1962), *The Myth of Simplicity* (1963), *Scientific Research* (1967), *Foundations of Physics* (1967), *Philosophy of Physics* (1973), *The Mind-Body Problem* (1980), *Scientific Materialism* (1981), *Philosophy of Psychology* (1987, with R. Ardila), the *Treatise on Basic Philosophy* (eight volumes, 1974-1989), *Finding Philosophy in Social Science* (1996), *Foundations of Biophilosophy* (with Martin Mahner, 1997), *Social Science Under Debate: A Philosophical Perspective* (1998), *The Sociology-Philosophy Connection* (1999), *Crisis and Reconstruction in Philosophy* (2000) and *Emergence and Convergence* (2004). Many of these books have appeared in Spanish, Portuguese, German, Italian, French, Polish, Russian and Hungarian editions. Other books have been published just in Spanish.

As well as writing books, Bunge has edited a number of important anthologies. These include: *The Critical Approach: Essays in Honor of Karl Popper*(1964), *Quantum Theory and Reality(1967)*, *Delaware Seminar in the Foundations of Physics* (1967), *Exact Philosophy* (1973), *Problems in the Foundations of Physics* (1971), and *The Methodological Unity of Science* (1973).

Royal Society of Canada and the American Association for the Advancement of Science; the recipient of Guggenheim and Killam fellowships; the Prince of Asturias prize; and five honorary doctoral degrees.

4. EARLY EDUCATION

Mario Bunge was born in Buenos Aires in 1919, the only child of Marie, who had been a nurse in Germany, and Augusto Bunge, a physician, sociologist, writer, and politician. Bunge's grandfather had been Chief Justice of Argentina. Augusto Bunge was the first socialist senator in Argentina; he was imprisoned for supporting trade union activism, and died some years later as a consequence of prison-induced illness. The father desired that his son should be 'a citizen of the world'. From an early age Bunge was set a demanding schedule of reading literature in six languages: Spanish, English, French, Italian, German and Latin, with Chinese read in translation. Modern Greek and Portuguese were added later. This early multi-lingualism was of inestimable benefit to his education, allowing him to read the classics and the best moderns in their own words. Multi-lingualism freed Bunge from dependence on commercial and ideological judgements about what books would be translated and published in Spanish. His reading of Heisenberg did not have to wait upon Spanish translations, nor did his reading of the major European and Anglo philosophers, especially the scientific philosophers of the Vienna Circle.

Bunge is critical of the mono-lingual limitations of Anglo-American scholarship, where mere bilingualism is considered praiseworthy. In a recent review of a major book on the sociology of philosophy Bunge laments that 'everything the author cites is in English, even when the available translations are notoriously unreliable – as is the case with Kant, Hegel, Frege, Husserl and Heidegger' (Bunge 2000, p.228). He criticises the author for discussing Descartes, but failing to mention two of his at-the-time most influential works. Pondering why this is the case, Bunge writes 'Let me hazard a guess: he does not know of their existence because until very recently, they were not available in English translation' (Bunge 2000 p.236).

Argentina in the 1920s and 1930s was anything but an open and progressive society; the Fascist and right-wing ideologies of Mussolini in Italy and Primo de Rivera in Spain were echoed by the ruling classes of Argentina. General Justo came to power in 1932 and presided over a Conservative, reactionary coalition government that looked favourably on Hitler and German Nazism, until it in turn was overthrown by a military junta in 1943. Argentina retained diplomatic relations with Nazi Germany until almost the end of the world war. The Catholic church was enormously powerful, with senior prelates having a strong voice in the deliberations of the government, military and ruling classes. The church influenced Argentinian philosophy through its own faculties of theology and philosophy; and it also influenced the teaching of philosophy in state universities. Scholasticism, neo-Thomism, Personalism, Phenomenology and various idealisms constituted the bulk of Argentinian, indeed Latin Marxism. Bunge set himself against all of these positions. As Quine observed, South American philosophy even up to the mid-1950s was a long way removed from its American and British counterpart. Bunge studied 'modern' philosophy on his own, and at age 20 gave his first public lectures on the subject.

While in high school, Bunge became interested in physics, philosophy and psychoanalysis, and wrote a book-length criticism of the latter. In 1938 he was admitted to the Universidad Nacional de La Plata, where he studied physics and mathematics. Shortly thereafter he founded a Worker's School, which was closed down by the government five years later, when it had 1,000 students enrolled. The students attended classes at the end of their working day. Bunge and his colleagues taught classes in basic science, history of the labour movement, labour law, economics, and political economy. This was in a culture where a conservative government and reactionary Church gave little support to science and even less support to workers' education or emancipation. From 1942-1944, Bunge was Secretary General of the Federación Argentina de Sociedades Populares de Educación. During this time he wrote his first book, *Temas de Educación Popular* (1943), that deals with the principles and practice of popular (workers) education. In the early 1950s he was imprisoned for a number of months by the Peronist government on charges of 'supporting an illegal strike'.

In 1943, he started to work on problems of nuclear and atomic physics under the guidance of Guido Beck (1903-1988), an Austrian refugee, a student of Heisenberg, the inventor of the layer model of the atomic nucleus, the first to propose the existence of the positron, and a teacher who Bunge thanks for 'teaching me not to allow politics to get in the way of my science' (Bunge 1991, p.524).

Bunge obtained his PhD in 1952 from the University of La Plata with a dissertation on the kinematics of the relativistic electron; the dissertation was published as a book in 1960. Subsequently he, alone or jointly with his former student Andrés J. Kálnay and other scientists, published several articles on a number of problems in quantum mechanics: the total spin of a system of particles, the mass defect of the H atom, new constants of motion, the quantum Zeno paradox, the measurement process, etc (Bunge 1944, 1945, 1955, 1956, 1967, 2003c).

5. DEFENDING THE ENLIGHTENMENT

Bunge's scholarly output is prodigious, and his achievements are remarkable. But a casual reading of any of his work immediately reveals that he is not just a wide-ranging scholar, at least in the sense of merely studying a variety of subject matters. As Quine noted, there is a 'headlong' aspect to Bunge's work, it is something that flows from his commitment to the Enlightenment Project; a project that began in the seventeenth century and flowered in the eighteenth. In one essay – 'Counter-Enlightenment in Contemporary Social Studies' – he writes:

> The Enlightenment gave us most of the basic values of contemporary civilized life, such as trust

> not do everything for us: no single social movement can do everything for posterity – there is no end to history. For instance, the Enlightenment did not foresee the abuses of industrialization, it failed to stress the need for peace, it exaggerated individualism, it extolled competition at the expense of cooperation, it did not go far enough in social reform, and it did not care much for women or for the underdeveloped peoples. However, the Enlightenment did perfect, praise, and diffuse the main conceptual and moral tools for advancing beyond itself. (Bunge 1994, p.40)

Bunge believes (*contra* contemporary constructivisms and relativisms) that science can, and does, give us knowledge of the natural and social world; and that this knowledge is the only sound basis for social and political reform, and for personal improvement. He is consequently a critic, indeed a trenchant one, of social forces and academic movements that diminish the intellectual authority of reason and of science. Thus in his writings one finds detailed critiques of:

> *New Sociology of Science (NSS)* - '… anyone with a scientific background is bound to regard most of the current production in that field as a grotesque cartoon of scientific research (Bunge 1991, p.525). 'The NSS is afflicted with behaviourism and pragmatism. As we know from the history of psychology, the former is a guarantee of psychological shallowness because it overlooks mental processes … we know from philosophy of science that [pragmatism] does not account for scientific research because it minimises the role of theory and identifies meaning with operationality and truth with efficiency. No wonder then that the NSS is characteristically shallow' (Bunge 1992, p.56).

> *Ethnomethodology* – 'they overlook the macrosocial context and are not interested in any large social issues' (Bunge 1996, p.100).

> *Radical Feminist Theory* – 'they want to undermine science, not to advance it. In this way they do a double disservice to the cause of feminism' (Bunge 1996, p.101).

> *Critical Theory* – 'by rejecting the scientific approach to social issues the critical theorists block understanding of such issues as well as any attempts to tackle them rationally and therefore effectively' (Bunge 1994, p.35).

> *Phenomenology* – 'It is characterised by spiritualism and subjectivism, as well as by individualism (both ontological and methodological) and conservatism – ethical and political…it is not a guide for any social policy other than "law and order"' (Bunge 1994, p.35).

> *Rational Choice Theory* – 'Rational choice theory … is not rational enough, …it adopts ontological and methodological individualism … it is far too ambitious … it is triply ahistorical …its hypotheses are empirically untestable … its spread is a tragicomic episode (Bunge 1999, p.100). 'We have found them wanting not for being "trapped within reason" – the traditionalist reproach – but for being trapped within the individualist and utilitarian dogmas, for invoking fuzzy basic notions and untestable key assumptions, for idealizing the free market, and for failing to match reality' (Bunge 1995/2001, p.318).

> *Bayesian Subjective Probabilities* – 'when confronted with ignorance or uncertainty, they use probability – or rather their own version of it. This allows them to assign prior probabilities to facts and propositions in an arbitrary manner – which is a way of passing off mere intuition, hunch or guess for scientific hypothesis' (Bunge 1996, p.102).

> *Behaviourism* – 'Discarding motivation, affect, and ideation, the behaviourist gives a superficial and therefore unilluminating account of behaviour; it is like a silent movie without titles' (Mahner 2001, p.269).

> *Hermeneutical Sociology* - 'It discourages objective observation, measurement, and mathematical modelling in social studies. Moreover this metaphor is pathetically inadequate, since social groups have neither syntactical or semantical nor phonological or literary properties. Its popularity is only due to the fact that it demands neither empirical investigation or mathematical modelling (Mahner 2001, p.184).

Bunge has sympathy for Marx and Engels – 'they were serious, important social scientists; they pushed liberalism towards the left ..; they were materialists on the whole; and they wrote clearly except about dialectics (Bunge 1994, p.30). But they 'learned from Hegel a few lessons that vitiated their whole system' (Bunge 1994, p.30). He sees no redeeming features in neo-Marxism and structuralist Marxism. Nor does he see anything but intellectual obfuscation in the neo-Romantic movement that 'began with Husserl's phenomenology, was followed by Heidegger's existentialism and culminated in "post-modernism" and the contemporary antiscience and antitechnology movement. Some of the best known names in this movement are …Spengler, Althusser, …Gadamer, Foucault, Derrida … Latour' (Bunge 1994, p.31). He recognises that the last list comprises a heterogeneous group, but they:

> share most or all of the following typically Romantic traits. These are (1) the mistrust of reason and, in particular, of logic and science; (2) subjectivism, or the doctrine that the world is our

> with symbol, myth, metaphor, and rhetoric; and (5) pessimism, or the denial of the possibility of progress – particularly in matters of knowledge. (Bunge 1994, p.32)

In the tradition of the Enlightenment, Bunge sees good education as being essential for human well being and social reform; however he despairs of a great deal of the education that he sees. Of university faculties of arts he writes:

> Here you will meet another world, one where falsities and lies are tolerated, nay manufactured in industrial quantities. The unwary student may take courses in all manner of nonsense and falsity. Here some professors are hired, promoted, or given power for teaching that reason is worthless, empirical evidence unnecessary, objective truth nonexistent, basic science a tool of either capitalist or male domination, or the like. … This is a place where students can earn credits for learning old and new superstitions of nearly all kinds, and where they can unlearn to write, so as to sound like phenomenologists, existentialists, deconstructionists, ethnomethodologists, or psychoanalysts. (Bunge 1996, p.108)

6. CRITICISING SCIENCE

The foregoing gives a sense of what Bunge is against; namely most of what is fashionable in contemporary social science and philosophy. But as the lead essay in this volume attests, he is not just a cheerleader for science, in the sense of endorsing whatever might be the current orthodoxy. He is equally a critic of tendencies *within* science that he believes are philosophically naïve, inconsistent, incoherent or inattentive to the big ontological and epistemological picture which is the goal of good science.

Bunge believes that the philosophical pronouncements and arguments of the great scientists, and more so the not so great ones, need to be closely examined and evaluated. When it comes to philosophy, scientists are as fallible as anyone else. He says of his decision to study physics at university that 'I wished to refute the influential idealist doctrines, now nearly forgotten, expounded in the 1930s by the astrophysicists Sir Arthur Eddington and Sir James Jeans' (Bunge 2003b, p.245). Susan Stebbing performed this refutation in her classic critique of these two famous physicists (Stebbing 1937/1958). In the mid-1960s Bunge criticised the great physicist Ernst Mach's positivist philosophical position. Bunge wrote of Mach's influential critique of Newtonian mechanics that:

> Mach's mistakes in his criticism of Newtonian mechanics – his most distinguished contribution to foundations research – can be corrected with the assistance of a bit of logic, a touch of semantics, and a dose of realism. A critical study of Mach's work in the foundations of mechanics should be helpful, if only to avoid repeating his mistakes, which were those of a philosophy will be the slave of one bad philosophy. (Bunge 1966, p.261)

Karl Popper, in his autobiography *Unended Quest* mentions Bunge as one of 'several important dissenters' from the post-World War Two dominant quantum theory interpretation of Bohr and his Copenhagen colleagues (Popper 1976, p.91). Bunge's dissent stems from his opposition to programmes that accept the positivist limitation on possible knowledge of unseen generative mechanisms, and that dogmatically insist that the object of knowledge is experience rather than reality.

Bunge is against all scientific programmes that accept and operate within the empiricist model of causation. One of Bunge's major books, translated into numerous languages, was a piece-by-piece demolition of the Humean empiricist account of causality, saying that 'it has been as erroneous as it is famous' (Bunge 1959/1979, p.88). In the book he substituted his own systematic account of causality, one that is prepared to relax causation and recognise the ubiquity of chance and spontaneity, but 'far from becoming indeterminists, we have enriched determinism with new, noncausal determination categories' (Mahner 2001, p.74).

Bunge opposes scientific programmes that are inappropriately reductionist, whereby they either ignore the emergence of properties and qualities out of extant elements, or persist in reducing the irreducible (Bunge 1977a). He distinguishes *reduction* as an epistemic operation from *reductionism* as a research programme. For *reduction*, to say that A is reducible to B, means that All As are B, or A is included in B, or A is a species of the genus B. For example, 'heavenly bodies are ordinary bodies satisfying the laws of mechanics'; 'heat is random molecular motion'; 'light beams are packets of electromagnetic beams' and so on. In contrast *reductionism* is a research programme or methodological principle according to which reduction is in all cases necessary and sufficient to account for wholes and their properties (Mahner 2001 p.168). Although reductionism should be pushed as far as possible, it cannot be entirely successful because all real things are embedded in some higher-level system, and interact with the members of that higher system. The general points concerning a critical approach to science that Bunge makes have been made often enough: first, not all science is good science; second even doing good science does not guarantee being able to articulate good philosophy. In an article on energy published in *Science* & Education Bunge says:

> New Age scribblers have no monopoly on nonsense about energy. Careless physicists have produced much such nonsense. In fact, energy is often confused with radiation, and matter with mass. (Bunge 2000, p.460)

He then discusses a list of conceptual mistakes concerning energy found in university physics textbooks. The list would have been far longer had he bothered to look at high school texts, or elementary school texts which are supposedly informing children about energy.

Lakatos, I. (1977). Proof and refutations the logic of mathematical discovery. Cambridge, USA: Cambrige University Press.

7. ARGUMENTATIVE STYLE

In the Introduction to their *Festschrift* for Bunge, Joseph Agassi and Robert Cohen say that he 'stands for exact philosophy, classical liberal social philosophy, rationalism and enlightenment', and they go on to comment that 'he is prone to come to swift and decisive conclusions on the basis of arguments which seem to him valid … he is emphatically autonomous in his judgment' (Agassi & Cohen 1982, p.vii). Exactness and quickness are recurring terms that are used to describe Bunge's style. In 1978 there was a celebrated occasion involving Bunge which is still remembered by many who were present, and that made the front page of a city newspaper. It was the International Congress of Philosophy held in Düsseldorf Germany, and Sir John Eccles – the famous neurophysiologist who collaborated with Karl Popper in articulating a dualist but interactionist theory of mind (Popper & Eccles 1977, Eccles 1980), and who had just been awarded the Nobel Prize - was invited to give the opening plenary address. Instead of the customary deference that might be expected to be given to a newly-minted Nobel laureate, Bunge, who was in the audience, stood up and accused Eccles of philosophical incoherence and of retarding the scientific study of mind. Many philosophers, including those who agreed with Bunge's views, thought that it was not the occasion for the arguments to be aired. Bunge has a different style.

In personal dealings Bunge is polite, attentive and concerned with the well being of those about him (office staff in the School of Education at UNSW where he spent a semester's leave in 2001, said he was the most polite, considerate and courteous visitor that the School had ever had); but in matters of scholarly debate he believes the argument should be stated as clearly and exactly as possible, and stated whenever warranted. He has no regard for 'soft-focus' writing or argument. Instead of saying 'It could be thought that there is a weakness in your argument', he prefers the more direct 'Your argument is weak'. Instead of warm and pleasant agreement about claims that cannot be tested, he seeks clear, specific hypotheses that can be tested against evidence. This style has had its professional price; it probably provides some explanation for why his wide-ranging and informed corpus of scholarship has not been as engaged with as one might expect. Clearly the works of many less-informed philosophers of science are more widely read than Bunge's.

8. PHILOSOPHY OF PHYSICS

In 1953 Bunge spent an important half year working on problems of realism and causality in quantum theory with David Bohm in Brazil (Bohm himself was a fugitive from the McCarthy Commission in the USA). In 1951 Bohm tried to reintroduce the classical concepts of position and velocity into quantum theory, he endeavoured to introduce them as 'hidden variables', that is dynamical variables with zero dispersion (Bohm 1951). For a while Bunge adopted Broglie, was right in defending realism, he was wrong in holding that realism demands that every dynamical variable has a sharp value under any circumstance and at any time. Bunge took the view that the very occurrence of the dispersion spreads in Δp (momentum) and Δx (position) suggest that quantum mechanics is about *sui generic entities*, that are neither classical particles nor classical waves. Being *sui generic* he thought these things deserved a name of their own, and suggested 'quanton'. Quantons are peculiar, in that they are non-classical entities, but that does not mean that they are either spooky or erratic; and it certainly does not mean that they entail a subjectivistic, non-determinate, immaterial world picture.

By the early 1960s Bunge realized that the only way to settle the raging controversies over the interpretation of quantum theory and relativity theory was to axiomatize the theories. As he says:

> For example, the subjectivistic interpretations of Heisenberg's famous 'uncertainty' inequalities are conclusively refuted upon showing that those formulas derive from assumptions that make no reference whatsoever to any observations, such as the Schrödinger equation (which contains no observer coordinates) and the Schwartz inequality (a purely mathematical formula). (Bunge 2003b, p.258)

In 1966 and 1969 Bunge met and discussed quantum physics with Werner Heisenberg, and later contributed to Heisenberg's *Festschrift* (Bunge 1977c). A point that he makes over and over about Heisenberg is that his deservedly famous 'Principle' - $\Delta p.\Delta x \geq h/4\pi$ (the product of the dispersions in the values of the momentum (hence the velocity) and the position of a microparticle is at least $h/4\pi$, where h is Planck's constant) – is not a principle at all, but it is rather a theorem. It is a derived formula that follows rigorously from the axioms and definitions of quantum mechanics. Because the formula is a theorem, to interpret it correctly one must examine the premises that entail it. Bunge maintains that such an examination shows that the formula is quite general. In particular it does not refer to a particle under observation: it is a law of nature, just as much as Schrödinger's equation, which is the basic formula of non-relativistic quantum mechanics. Thus the popular name 'Uncertainty Principle' for it is incorrect. As Bunge notes, uncertainty is a state of mind, and quantum mechanics is not about minds but about physical things, most of which are beyond the experimenter's reach.

One of Bunge's most important early books was his *Foundations of Physics* (Bunge 1967) which was written in Freiburg under the auspices of the Alexander von Humboldt Foundation. This book expounds a new type of physical axiomatics, one wherein every formula is accompanied by a semantic assumption elucidating the physical meaning of the basic (primitive) concepts. In order to do this, Bunge worked extensively to develop a sophisticated semantics, factual interpretations could be given to mathematical formalisms. This 1967 book has been updated in recent years by the Mexican Guillermo

The book rejected both the Copenhagen and the Bohm interpretations of quantum theory, and proposed a realist interpretation. This keeps the mathematical formalism but modifies the positivist interpretation proposed by Bohr, Heisenberg, Pauli, and Born. For instance, Bunge interprets the square of the absolute value of the state function not as the probability of finding the object in question in a unit volume (an intrinsically subjective notion), but as the probability of its being there (an objective notion). Bunge argues that electrons and the like are neither particles nor waves, although they appear as such under special circumstances. Talk of waves and particles is metaphorical, an allusion back to classical notions from which quantum mechanics emerged. He coined the term 'quanton' to denote these non-classical entities, and maintains that mature quantum theory has no need for the classical metaphors, just as mature electrodynamics has no need for mechanical analogs (Mahner 2001, p.183

9. A PHILOSOPHICAL SYSTEM AND PROGRAMME

Bunge has developed a philosophical system that may be characterized as: materialist (or naturalist) but emergentist rather than reductionist; systemist rather than either holist or individualist; rational-empiricist rather than either rationalist or empiricist; science-oriented; and exact, that is, built with the help of logical and mathematical tools rather than depending upon purely verbal articulation. He maintains that:

> Physics cannot dispense with philosophy, just as the latter does not advance if it ignores physics and the other sciences. In other words, science and sound (i.e., scientific) philosophy overlap partially and consequently they can interact fruitfully. Without philosophy, science loses in depth; and without science philosophy stagnates. (Bunge 2000, p.461)

His system is laid out in detail in his monumental eight-volume *Treatise on Basic Philosophy* (1974-1989), where individual books are devoted to Semantics, Ontology, Epistemology, Philosophy of Science and Ethics. He has applied his system approach to issues in physics, biology, psychology, social science, technology studies and science policy. An accessible source of his position is a collection of essays *Scientific Realism: Selected Essays of Mario Bunge* (Mahner 2001). The essays range over nine fields of philosophy – Metaphysics, Methodology and Philosophy of Science, Philosophy of Mathematics, Philosophy of Psychology, Philosophy of Social Science, Philosophy of Technology, Moral Philosophy, Social and Political Philosophy. There have been two volumes devoted to amplification and criticism of Bunge's work, the above-mentioned Agassi and Cohen *Festschrift* (1982), and an edited volume discussing his *Treatise* (Weingartner & Dorn, 1990). Bunge has himself provided an account of his philosophical apprenticeship and mature position – 'Philosophy of Science and Technology: A Personal Report' (Bunge 2003b).

Bunge believes that the lessons learnt from the hard-won successes of natural science should be applied to social science; the inquiry template forged by the best of natural science can and should be applied to the social and psychological worlds. Apart from insufficient funding, he regards bad philosophy as the major obstacle to the advance of social science. He sees the philosophical deficiencies as logical, ontological, epistemological and ethical. The logical flaws are conceptual fuzziness and invalid inference; the ontological culprits are individualism and holism; the epistemological errors are sectoralism or tunnel vision, subjectivism, apriorism, pragmatism and irrationalism (Bunge 1998, p.452). There are two major moral lapses that contribute to the backwardness of social science:

> One is the frequent violation of the ethos of science, first ferreted out by Merton (1938). Such violation occurs, in particular, when the universality of scientific knowledge is denied, dogmatism is substituted for 'organized scepticism'….and rigorous testing, or at least testability is jettisoned. The second moral culprit is the attempt to pass off ideology (left, centre or right) for science in basic research, the pretense of moral or political neutrality when tackling practical issues. (Bunge 1998, p.453)

10. PHILOSOPHY AND THE TEACHING OF QUANTUM PHYSICS

The epistemological, ontological, metaphysical and cultural aspects of quantum theory should be addressed when the subject is taught. Any inquisitive student learning about quantum physics will have philosophical questions, and they will be receptive to the historical story that features so many giants of modern physics - Einstein, Bohr, Planck, Heisenberg, Schrödinger, Born and Dirac. As one physicist/philosopher has written:

> The development of quantum mechanics led to the greatest conceptual revolution of our century and probably to the greatest that mankind had ever experienced. It most likely exceeded the great revolutions in our thinking brought about by the Copernican revolution, the Darwinian revolution, and the special as well as the general theory of relativity. Quantum mechanics forced us to reconsider our deepest convictions about the reality of nature. (Rohrlich 1987, p.136)

Quantum theory is tailor made to advance curricular demands for infusing the history and philosophy of science into science programmes. But the teacher needs knowledge of, and enthusiasm for, the history and philosophy of the subject in order to respond to student questions and in order to prompt those questions from less inquisitive students. Without such input, learning the theory collapses into just more lessons in higher mathematics mixed with some bizarre accounts of cats that are half alive and half dead, and of tiny entities on one side of the world changing their orientation because their 'sibling' entity on the other side of the world changed its

theory is the message of Mario Bunge's lead article in a 2003 special issue of *Science & Education* devoted to 'The Philosophy and Teaching of Quantum Theory' (Bunge 2003a).

CONCLUSION

Bunge is one of a small number of scholars able to competently range over the disciplines of physics, social science, psychology, biology, history of science and philosophy. Such competence is slowly disappearing. From graduate student years, through to tenure decisions and beyond, there are enormous pressures on academics to specialise; and as the cliché has it, to learn more and more about less and less. This is a misfortune for the conduct of science as, among other things, it severely limits cross-disciplinary fertilisation and research programmes. It is a misfortune for the conduct of science education research where competence in science, philosophy and psychology is needed to avoid the all-to-common wasted effort caused by passing philosophical and methodological fads that distract, if not completely derail, the research community – for instance, behaviourism in the 1960s and 70s and constructivism in the 1980s and 90s (Matthews 2000, 2004).

Bunge is a defender of science and a promoter of good and engaging science teaching; he recognises that without science teachers there would be no science. Defending science against its social and academic detractors, and promoting good science teaching, depends on a broad knowledge of science, its history and its philosophy. Without this, the interconnectedness of the scientific endeavour is lost, and the rich impact of science on the history of culture is ignored. When Bunge was ten years old, a popular text used for the preparation of English science teachers was published. The author, F.W. Westaway had some of the attributes of Bunge: he was trained as scientist, he wrote on scientific method (Westaway 1919), on the history of science (Westaway 1934), and he was His Majesty's Inspector for Science in English Schools. On the opening page of his textbook he characterised a successful science teacher as one who:

> knows his own subject . . . is widely read in other branches of science . . . knows how to teach . . . is able to express himself lucidly . . . is skilful in manipulation . . . is resourceful both at the demonstration table and in the laboratory . . . is a logician to his finger-tips . . . is something of a philosopher . . . is so far an historian that he can sit down with a crowd of [students] and talk to them about the personal equations, the lives, and the work of such geniuses as Galileo, Newton, Faraday and Darwin. More than this he is an enthusiast, full of faith in his own particular work. (Westaway 1929, p. 3)

Westaway had high expectations for science teachers: Mario Bunge shares them, and meets them.

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