Mackay, Alan L. (1999) From "the dialectics of nature" to the inorganic gene. *Foundations of Chemistry* 1 (1) 43-56.

Foundations of Chemistry **1**, 43-56, (1999)

# From "The Dialectics of Nature" to the Inorganic Gene

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Dialectics, the ancient technique[1] of the sophists who sought, by argument and counter-argument from agreed pre-suppositions and logical structure and with common value systems, to establish the truth[2], has been refined and made more precise and has resulted in techniques like the genetic algorithm, which is a mathematical procedure for searching widely over a multi-dimensional configurational or parameter space, escaping from local minima, until a better solution, although perhaps not absolutely the best, is obtained. A measure of what is better or worse is, of course, also necessary. It operates like evolution by variation and natural selection of the fittest. The technique depends on being able to separate the problem into the real situation and its description in other terms and to translate or project backwards and forwards between these two alternative worlds, different in nature and not just opposing tendencies, which can be seen as hardware and software, body and soul or battlefield and map. Every creature has in its brain such a transformed model of its surroundings and of itself and can carry out potential operations with this model to assess possible outcomes. On this basis it can act in the real world. Thus, the dialectical tennis of the philosophers[3], unrewarding for scientists, has now become explicit mathematics which, with computer models which embody appropriate results of experimental observations, can be useful. Chemistry, mimicking biology, has found the concept of the inorganic gene to be useful in exploring configurational space, but the implications are wider.

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[1] The footnote itself is an essential part of the technique of exposition expanding a linear discourse into a branched tree structure. See: Anthony Grafton, "The Footnote, a Curious History", Faber and Faber, London, 1997.

[2] "What is truth said jesting Pilate and would not wait for an answer" (Francis Bacon) and the debate about the post-modernist attribution of equal validity to all systems of viewing the universe has now reached (the journals) Nature and Science. This debate on modern sophistry reached a peak with the appearance of Alan Sokal's spoof paper, "Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity", Social Text (46/47), pp. 217-252, (1996) and this attack has been compounded with a book "Impostures Intellectuelles" by Alan Sokal and Jean Bricmont. These documents and much resulting comment, are to be found on the Internet under the "Sokal Affair". Sokal is at http://www.physics.nyu.edu/faculty/sokal/ and the text is at http://www.h-net.msu.edu/~nexa/links.html

[3] We cannot take philosophers very seriously. Roger Scruton, for example, in "Modern Philosophy", London, 1994, p. 571, writes: "The study of space and time is complicated by the intrusion of physics."

Originally, in classical Greek times, dialectic was a method of enquiring into truth, by verbal disputation, with only slight reference to experiment and observation. It was refined by the Jesuits who introduced an official *advocatus diaboli* to test self-consistency and the soundness of the logic and this is still the practice in oral examinations for a doctorate[4] — only the fittest arguments survived and the truth evolved from the disputation, although the system contained the assumption that the truth lay within the framework, often theological, prescribed by the system itself. A less formal but more important example was the *Coterie Holbachique*, the dining group of the Enlightenment. Baron d'Holbach provided the immeasurably valuable subsidy to science and learning by giving dinner in his house in Paris for twenty people twice a week for thirty years. The leading figure was Denis Diderot (1713-1784)[5] and several members contributed to the Encyclopaedia but many other significant people attended, including foreign visitors such as Benjamin Franklin and the intellectual climate of the eighteenth century was formed through the uninhibited discussions to and fro in an informal dialectic which took place in freedom and privacy. Although several figures were atheists several clerics attended. There have been many other such dining groups[6] which sought by discussion to form a common intellectual atmosphere but none so important. Nowadays, "think-tanks" have a different character.

G. F. W. Hegel (1770-1831) produced a philosophical system of considerable obscurity, called the dialectic, of "thesis, antithesis, synthesis" to account for change[7]. "At the foundation of Hegel's thought was his understanding of dialectic, according to which every state of being inevitably brings forth its opposite. The interaction between these opposites then generates a third stage in which the opposites are integrated • they are at once overcome and fulfilled • into a richer and higher synthesis, which in turn becomes the basis for another dialectical process of opposition and synthesis"[8]. Hegel greatly influenced later German thought, in particular, that of Friedrich Engels and of Ernst Haeckel. The opposites were conceived of as being of similar status, like left and right, and not as completely different like word and deed.

Friedrich Engels (1820-1895) about 1875 developed his constructive philosophy of dialectical materialism[9] which became the official "world outlook of the Marxist-Leninist

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[4] Continental, especially Russian, public doctorate examinations have an official "opponent" and are often occasions for a clash between rival schools which sometimes obscures even the candidate.

[5] Diderot's embryonic ideas on evolution, organisms and life can be seen in his scandalous essay "D'Alembert's Dream" (1769).

[6] In Victorian Britain there were the "X-club", the Philosophical Club, the Coefficients and many others. In the 1930 and 40s the "Tots and Quots" (*quot homines tot sententiae)* was significant in applying science to the problems of the war.

[7] A. J. P. Taylor wrote: "For the first time thinkers made their peace with movement instead of insisting on a static universe. They were in fact fumbling towards the idea of evolution, which was perhaps the greatest creative idea of the nineteenth century". Introduction to "The Communist Manifesto", Penguin Books, 1967.

[8] R. Tarnas, "The Passion of the Western Mind", New York, 1993. p.379.

[9] Engels wrote to Marx (30 May 1873): "This morning when I was in bed I had some dialectical ideas about the natural sciences. ... If you think that I have got hold of something here please keep it to yourself. I do not want some lousy Englishman to steal the idea. And it will take a long time to get it into shape". (qu. W. O Henderson, "Engels: Selected writings", Penguin, 1967. p. 393.)

Party” of the USSR[10], although his notes on his philosophy of science were published only about 1935[11]. Engels’ dialectics was developed from the formal dialectics of G. F. W. Hegel. It was then obligatory on the Continent to have a formal philosophy[12]. Nothing is more characteristic of the British ruling class of the present time than their contempt for science and technology, the material basis for the production of the wealth which sustains them, unless it is their scorn for theory in general. J. D. Bernal also wrote: ``In England, more than in any other country, science is felt rather than thought. A defect of the English is their almost complete lack of systematic thinking. Science to them consists of a number of successful raids into the unknown."[13] For example, The Times recently published a major article to the effect that “The national curriculum puts a quite unrealistic emphasis on science and mathematics, which few of us ever need"[14], whereas in the Victorian period even the SPCK (Society for the Propagation of Christian Knowledge) could produce “A Catechism of the Steam Engine" so that all could understand the forces then changing society[15]. Victoria’s consort Prince Albert, educated in Germany, was very much aware of

[10] for example: M. Cornforth, “Dialectical Materialism”, Lawrence and Wishart, London, 1952.

[11] F. Engels, “Dialectics of Nature”, Foreign Languages Publishing House, Moscow, 1954.
It should not be thought that Engels was an armchair philosopher. He was familiar both with the world of industry and with the slums of Manchester, describing these in “The Condition of the Working Class in England” (1844).

[12] We have acquired the word *Weltanschauung* - (world outlook) from the German philosophers, since there seems to be nothing quite so theoretical in English.

[13] “The Social Function of Science”, 1938. p.197.

[14] Simon Jenkins, The Times, 11 May 1994. p.18.

[15] Birkbeck College of London University, from which I write, was founded in 1823 as the London Mechanics Insitute, of which Robert Malthus wrote: “above all, the Mechanics Institutions, open the fairest prospect that, within a moderate period of time, the fundamentals of political economy will, to a very useful extent, be known to the higher, middle, and to a most important portion of the working classes of soci[15] Diderot’s embryonic ideas on evolution, organisms and life can be seen in his scandalous essay “D’Alembert’s Dream” (1769).

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the role of science and technology and himself organised the Great Exhibition of 1851 to emphasise Britain's pre-eminence in this. In our period Paul Kennedy's thesis is that political and military power spring from technological power.

Even Mrs Thatcher sometimes realised this lack of theoretical understanding and of a *Weltanschauung*. She told the Conservative Philosophy Group: ``We must have an ideology. The other side have got an ideology they can test their policies against. We must have one as well."[16] Chemists (among whom Mrs Thatcher liked to count herself) are in general more apolitical than most scientists and regard with distaste the continental tradition of having a compulsory philosophy examination as part of the Ph.D. course. This long tradition carried over into the general courses in dialectical materialism which formed part of the general ideological education in the USSR and was not a specific Soviet invention. The English managed quite well without a philosophy whereas, for example, Lenin spent a month in the British Museum Library writing to refute the philosophical doctrines of (among others) his rival A. A. Bogdanov (1873-1928) and Marx worried even about the philosophy of mathematics[17].

Marx and Engels "stood Hegel on his head" and adapted his form to their own ends. It was a period of great change not only technologically but politically as revolutions swept Europe in 1848 so that a theory of change was necessary. Marx and Engels wrote the Communist Manifesto in 1848 and took very active parts in the events of the time. During his stay in Manchester (185-1870) Engels was much influenced as regards science by Carl Schorlemmer (1834-1892)[18], whom he met at the Schiller Anstalt[19] in Manchester. Schorlemmer (elected FRS in 1871), who became the first professor of organic chemistry in Britain (at Owen's College), was concerned with the chemistry of the oil newly discovered in Pennsylvania, and the mantra of dialectical materialism about the "transformation of quantity into quality", promulgated in the textbook *Fundamentals of Marxism-Leninism*[20] derived directly from Schorlemmer's studies of the series of hydrocarbons with increasing numbers of carbon atoms[21]. At much the same time the mathematician J. J. Sylvester noted the surprising connections between algebra and chemical structure[22], a branch of mathematics now increasingly active and important with the advent of the computer and comprehensive data bases. But, for example, N. I. Bukharin, the chief exponent of science in

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ety in England. "An Essay on the Principles of Population", 1798.

[16] qu. Hugo Young, "One of Us", Macmillan, London, 1989. p.406.

[17] The Marx-Engels Archive is alive and well and living in Colorado at http/:csf.colorado.edu/psn/marx

[18] "Carl Schorlemmer 1834-1892", Merseburg (DDR), 1974.

[19] The Schiller Anstalt was an important club where Germans, who had been attracted to Manchester as the centre of the Industrial Revolution, gathered socially. Karl Halle, founder of the Halle Orchestra was a member, as was Ludwig Mond the founder of Imperial Chemical Industries.

[20] (ed. O. Kuusinen), "Fundamentals of Marxism-Leninism", FLPH, Moscow, 1963.

[21] In pursuit of his studies of oil Schorlemmer, in 1888, visited Pennsylvania with Engels.

[22] J. J. Sylvester, "Chemistry and Algebra", Nature, **17**, 284, 309, (1877/78)

the Bolshevik Party[23], insisted that change need not be gradual: "The transformation of quantity into quality is one of the fundamental laws in the motion of matter; it may be traced literally at every step both in nature and in society." "the notion that nature permits of no such violent alterations is merely a reflection of the fear of such shifts in society". With the emergence of computers the complex phenomenology of non-linear systems can now be handled much more expeditiously and the results have influenced even philosophy by illuminating concepts such as "reductionism" and "determinism".

Engels was a major channel for the input of science[24] into the Marxist-Leninist world outlook and he introduced Schorlemmer to Marx in Manchester. Manchester was the centre of the Industrial Revolution and many foreigners, envious of its success, came there to see how it worked[25]. The first enterprises to apply power and technology to production earned enormous rates of return, until their monopolies could be broken. With this vision of industrialisation, Lenin, prompted by Bukharin[26], tried to carry out something like the (Chinese) Great Leap Forward, by jumping directly from steam power to electric power. "Communism is Soviet power plus the electrification of the whole country" • was a major slogan of the 1920s. Thus, Engels, although beginning with the Hegelian concept of struggle between two opposing tendencies, like the class struggle, advanced to the idea that something completely new, not just a compromise, might emerge from the conflict.

The basic principle governing change is, besides the laws of thermodynamics, the principle of evolution enunciated by Darwin in his "Origin of Species" in 1859. This was of the greatest interest to Marx, Engels and many others, and particularly to the biologist, Ernst Haeckel (1834-1919) who, like T. H. Huxley in Britain, promoted Darwin's ideas in Germany. It is important to note that at that time there were close connections between politics and science[27]. Yet, although Darwin elucidated the mechanism of evolution, he could say nothing about the hereditary substance and the material mechanisms by which the contributions of the two parents were combined and transmitted. The atomic basis of this mechanism was revealed in 1953 in the structure of DNA, discovered by Francis Crick and J. D. Watson, which marked a turning point in human history only now becoming fully appreciated with the commercialisation of the manipulation of substances, not directly as organisms or chemicals, but through their genetic representations.

Haeckel spent most of his life as Professor of Biology in Jena. He was more a naturalist than an experimental scientist and was particularly engaged in propagating Darwin's theory of evolution but he was, as a polemicist, even in his own time, found to be careless of the

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[23] Also editor of the "Great Soviet Encyclopaedia", leader of the delegation to the 1932 Congress on the History of Science, etc. He once offered the whole electricity supply of Leningrad for one day to George Gamow for an experiment perhaps foreshadowing nuclear fusion.

[24] S. F. Cohen, in "Bukharin and the Bolshevik Revolution", Wildwood House, London, 1971.

[25] Engels had written, very presciently, "Modern industry has established the world market" (Communist Manifesto, 1848).

[26] "... we must do our utmost to promote the union of science with technique and with the organisation of production. COMMUNISM SIGNIFIES INTELLIGENT, PURPOSIVE AND CONSEQUENTLY, SCIENTIFIC PRODUCTION. WE SHALL, THEREFORE, DO EVERYTHING IN OUR POWER TO SOLVE THE PROBLEM OF THE SCIENTIFIC ORGANISATION OF PRODUCTION." *Azbuka Kommunizma*, Peterburg, 1920. (Bukharin's capitals).

[27] Two fellows of the Royal Society were among the 20 or so people who attended the funeral of Karl Marx in 1883.

soundness of his evidence and did not apologise or correct himself when found to have supported his arguments with mistaken pictures. He is best known now for his descriptions of radiolaria and diatoms from the Challenger Expedition and particularly for the drawings (etched by E. Giltsch but earlier by Wagenschieber) contained in these reports[28] which have often been reprinted and reproduced. Haeckel was also a gifted amateur artist (as was Louis Pasteur) and produced about 1000 sketches of his biological travels.

Haeckel, in opposition to religion, and particularly in opposition to the Catholic Church, sought to give a non-religious account of the origin and operation of life. His polemic book “The Riddle of the Universe” (1899) sold more than 500,000 copies. However, Haeckel created for himself a new religion, *monism*, which had political objectives, although it is unfair to blame him retrospectively for the later ideology of the Nazi Party[29], and he obscured the straightforward materialist picture. Although he called his doctrine *monism* it was in fact a *dualism* and Haeckel confusingly re-defined the concept of *soul* for his own purposes. What Haeckel realised was that matter by itself had to operate with some organising principle, like hardware and software, but he could find no material structure for this[30]. In emphasising the continuity of all nature, he deduced that if human beings had souls and mental life, so must all other beings, right down to the atomic level[31]. In describing the intricate symmetrical order of single-cell organisms it was obvious to him that there must be a blue-print or plan embedded in the organism and not imposed from outside by a creator. The topic of morphogenesis is now very active and it is becoming apparent that the biological “living” component of a cell is the dominant partner and “uses” various chemical and physical phenomena which have become symbiotically enveloped into the mechanism. A clear example of this is the survival value imparted to magneto-tropic bacteria by the presence of grains of magnetite, which lead it to swim down into the anaerobic mud at the bottom of a pond. Bacteria in the North and South magnetic hemispheres are oppositely magnetised. Bacteria which swim up to the surface do not reproduce as well.

Almost at the end of his life, Haeckel seized on the discovery by Otto Lehmann (about 1904) of the phenomena of liquid crystals, which furnished a clear and simple example of self-organisation. Lehmann himself claimed that this was an example of the simplest

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[28] Stimulated by Haeckel's drawings of radiolaria a 25m span geodesic dome was constructed for the Zeiss Planetarium in Jena (Haeckel's home town) in 1925/26 (first version 1923), long before Buckminster Fuller. It survived the air-raids. The metal framework was embedded in concrete, only 6cm thick, so that the steel network became invisible. Similar domes had been built in various cities, including Chicago (1930) by the Zeiss-Dywidag System. See, for example: "Jena und Umgebung", VEB Tourist Verlag, Berlin-Leipzig, (1977). p.83.

[29] D. Gasman, "The Scientific Origins of National Socialism", Macdonald, London.

[30] We may think of Bernard Shaw's play "Misalliance" where Tarleton says: "I've got a soul: dont tell me I havnt. Cut me up and you cant find it. Cut up a steam engine and you cant find the steam. But, by George, it makes the engine go".

[31] Freeman Dyson wrote much more recently: "But I, as a physicist, cannot help suspecting that there is a logical connection between the two ways in which mind appears in my universe ... I think our consciousness is not just a passive epiphenomenon carried along by chemical events in our brains, but is an active agent forcing the molecular complexes to make choices between one quantum state and another. In other words, mind is already inherent in every electron, and the processes of human consciousness differ only in degree but not in kind from the processes of choice between quantum states which we call `chance` when they are made by electrons." *Disturbing the Universe*" Harper and Row, New York, 1979

possible “inorganic life” and Haeckel took up this line at the age of 83 in his last book “Crystal Souls • Studies of Inorganic Life” (1917)[32]. He was not original in this and many people, especially in Germany, had been seduced by the over-simple-analogy between the growth of crystals and the growth of cells. This is the central point of our argument. It was not then realised that cells have a built-in store of information which guides their development, whereas crystals grow only by the general shaking down to a state of minimum energy. The chain led through Goethe to Schleiden, Schwann and Weismann[33] (and remnants of Naturphilosophie are still kept alive in the school of Rudolf Steiner). Haeckel related the self-organisation of liquid crystals to the external shapes of the skeletons of radiolaria and diatoms which he had described, with exceptionally beautiful drawings, in materials from the Challenger Expedition. He lacked the concept of information and found it necessary to regard these single-cell organisms as endowed with some organising principle which he called “soul”, then not having any idea of the actual material mechanisms carrying the necessary information which only really began to become clear after the discovery in 1953 of the arrangement of atoms in the genetic apparatus and later of the genetic code and the molecular basis of evolution.

Evolution works by a ratchet mechanism, not necessarily in the direction of what human beings may regard as “progress”• the parasitic tapeworm is also the highest product of evolution • and depends on the generation of variants of a structure and “the survival of the fittest”. These ideas have recently been given new twists into new directions by John Maynard Smith and Eörs Szathmáry and by David Mermin. The former suggest that the macrocosmos may even have evolved by the selection of black holes (Nature, 14 Nov. 1966 and, at the lower end of the scale of size, David Mermin said of the microcosmos: "It is because nothing required us to apprehend atomic structure during our evolutionary development that we are incapable of understanding what it is that quantum physics describes." (Nature). There is still more mileage in the concept of evolution by natural selection and the genetic algorithm[34], mentioned above, is based on this principle and is used in computer science, for example in designing new molecules.

Evolution, as exhibited by the DNA/Protein system, is not the same as dualism. In mathematics, the process of inversion of a geometrical structure in a circle (if in two dimensions) or in a sphere (for three), or the procedure of conformal transformation, gives a structure which is strictly equivalent, but where symmetries can be shown up by the choice of inversion centre. Thus the packing of five mutually tangent spheres of different radii is difficult as it stands but, after inversion to make them all of the same radii (or planes), become trivial. One goes backwards and forwards without progress. Similarly, in crystallography, the Fourier transformation of a periodic structure gives another three-dimensional (reciprocal) lattice, which is important because it relates closely to the data derived from X-ray diffraction, but the transformation is completely reversible and performing it twice returns the original structure.

The natural language of DNA/protein, the genetic code is very appropriately termed a language[35]. Hitherto we have only recognised the languages used by human beings in

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[32] E. Haeckel, “Kristallseelen”, Leipzig, 1917.

[33] J. Lorch, “The Charisma of Crystals in Biology”, in “The Interaction between Science and Philosophy”, ed. Y. Elkana, Humanities Press, 1975.

[34] A purely computer example is to be found in The Mathematica Journal, **3,** (2), 52-55, (1993).

[35] The development of natural languages and of the human genome agree in the information they give on the migration of human beings.

mutual discourse and the dialectic depends on projecting some material situation into words, which are then manipulated and transformed back again into conclusions about the real material world. A situation transformed into language and back again arrives back somewhat different because a description is never a complete description.

Having recognised that DNA is a "description" (or prescription) containing information for a protein sequence, we can ask where the corresponding description or programme for other structures may be. It then appears that in other structures the information is more diffusely stored. The structure of complex minerals appears as a result of local rules and there is no concentrated informational organ. The recognition of the concept of information as a parallel to structure has transformed our attitudes to complexity. We now look for the programme giving rise to the complexity and can define complexity of a structure in terms of the minimum programme which could give rise to it.

The essential for evolution is that there should be two systems and processes of translation from one to another. A physical system and its description in *some other language* supply the pertinent example. The process of translation is really a generalised projection and the key feature of projection is that it is irreversible, because information is lost in the process, and the original system can only be restored if other knowledge is introduced. Thus, to restore a locomotive from a blue-print requires a knowledge of contemporary engineering technology. To make a blue-print of a locomotive requires the ignoring of a mass of standard features *which every engineer knows.*

Biological systems are the most remarkable because both protein and gene are built of the same atoms, subject to the same laws of chemistry. Essentially the DNA sequence corresponding to a protein is the address, in configuration space, of the protein sequence. This means that, given the sequence and appropriate machinery, we can go straight to the address. In ordinary chemical synthesis the point representing the state of the system has to be navigated through the multi-dimensional energy landscape, like Waddington's epigenetic landscape, and like a ball on a pin-table, by tilting the machine (for example, by changing the concentrations and temperature) to get the ball into the required hole. In biosynthesis, we can give the address of the hole and make the required protein by going to it directly. It is unrealistic to think of a protein like lysozyme as being a metastable phase in the system C/N/O/H/S. The address in configuration space is an equivalent description of the molecule. If we give the wrong address we get to the wrong place. The topology of this configuration space may be very complicated.

In computing, the genetic algorithm[36] follows the ideas of natural evolution. We deal with the evolution of some structure, very generally conceived with some criterion of value in mind. It is necessary to have a description of this structure in a form which can be edited. A linear 1-D structure is easy to edit; a 2-D structure, such as the front page of a newspaper is more difficult and a 3-D structure is prohibitive.

If we wish to model a three-dimensional structure, such as a silicate, then a linear description is required. Mathematics, executed now by computer, is also now beginning to furnish us with an "inorganic gene[37]" with which we can first describe, classify and predict inorganic structures and which may eventually facilitate their synthesis as proteins are now synthesised.

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[36] John Holland, "Genetic Algorithms", The Scientific American, July 1992. 44-50. D. E. Goldberg, "Genetic Algorithms in Searches, Optimization and Machine Learning", Addison Wesley, Reading, MA., 1989.

[37] A. L. Mackay, "Generalised Crystallography", Jour. of Molecular Structure (Theochem), **336**, 293-303, (1995).

Earlier philosophical systems analysed economics and society as equilibrium systems, in many cases fixed by the unchanging dogmas of sacred texts. Change can now also be handled. Newton and Leibnitz provided the tools for physics and Hegel introduced the idea of dialectics in philosophy. In science there are many new ways of handling change, for example, the epigenetic landscape of C. H. Waddington for biology, all kinds of computer simulations of systems ranging from the Solar system (found to be weakly chaotic) to the British economy. Arthur Winfree, a pioneer in dealing with non-linear systems, gave his book the intriguing title "The geometry of biological time" indicating that changes in time and space were intimately mixed (as also in relativity) although Joseph Needham had much earlier written: "form is simply a short time-slice of a single spatio -temporal entity". The sudden changes in such systems have been illustrated in the 'catastrophe theory' of Ren★ Thom which has been expounded by Christopher Zeeman for social as well as for physical systems. They find that there are only seven types of geometrical singularities in the configuration space. These are by way of being mathematisations of the "double bind" kind of situation which philosophers describe where one can get out of a knot only by jumping to some other position.

A current danger is that presented by the fashion of post-modernism, where all systems of analysing the world may be regarded as equally valid and the material basis of the world is hardly distinguished from its verbal representation, although the scientific world has the distinction between software and hardware as a dominant concept. However, there have been counter attacks, besides that by Sokal[38], for example by Ernest Gellner, who insists on the reality of things and as a social anthropologist standing between the physical and social sciences, gives a marvellous statement[39] of what science is[40]. We must recall Dr Johnson's simple refutation of solipsism: "Dr Johnson struck his foot with mighty force against a large stone, till he rebounded from it, saying, 'I refute it thus'". The division is between those who actually work with things and those who manipulate the media. For the latter the word may become more real than the mere facts. But, as Burns put it: "Facts are chiels that winna ding, an' downa be disputed" [facts are facts]. More and more, for example with the examination by PET (positron emission tomography) the living brain can, with the methods of science, be seen at work on intellectual tasks, so that the preserves of the philosophers and the humanists are being enfolded into the domain of science and science takes more and more note of all other human concerns[41] such as art, language and emotions. We are in an

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[38] In May 1995 the NY Academy of Sciences held a symposium published as: "The Flight from Reason", ed. P. R. Gross and N. Levitt, Johns Hopkins Press, Baltimore, 1997.

[39] E. Gellner, "Post-modernism, Reason and Religion", Routledge, London, 1992.

[40] (ibid. p.58.) "natural science ... 1. Its propositions and claims are translatable without loss of efficacy into any culture and any milieu. 2. In its applied or technological form, this new knowledge has totally transformed the human social condition, and the terms of reference under which mankind lives. ...
3. In its internal organisation, the new learning which makes the new social order possible is both cumulative and astonishingly consensual. ... 4. This new learning respects neither the culture, nor the morality, of either the society in which it was born, or of those in which it makes itself at home by diffusion. It is, most emphatically, 'beyond culture and morality'. ... Past belief systems were technically spurious and morally consoling. Science is the opposite. ... Its failure to legitimate social arrangements, and to make men feel at home in the world, is the commonest charge levied at science. This charge is entirely valid."

[41] For example the journal Nature has, over the last few months, carried a column on visual art.

agreeable period of synthesis, but the dualities of software and hardware are at present dominant brought home by the spread of the computer.