The essence of emergence

Michael Berry

The Quark and the Jaguar: Adventures in the Simple and the Complex. By Murray Gell-Mann. *W. H. Freeman/Little, Brown: 1994. Pp. 392. $23.95, £18.99.*

WHILE walking in a South American rainforest and thinking about quantum mechanics, Murray Gell-Mann encountered a jungle cat. They stared at each other for a while, then the cat turned away and disappeared among the trees. Gell-Mann employs this meeting as a metaphor for the central question to which his book is devoted: how can the fundamental laws of physics, pre-eminent of which is quantum mechanics, conducting an orchestra of elementary particles such as quarks, produce a diversity of complex organisms such as the jaguar? This is, on the grandest scale, the problem of reduction, that is, of intellectual continuity between the partial descriptions provided by different sciences on different levels. He is brave to attempt this, because of the prejudice "that serious work is restricted to beating to death a well-defined problem in a narrow discipline, while broadly integrative thinking is relegated to cocktail parties". The attempt is heavily influenced by his recent experiences at the Santa Fe Institute for the study of complex systems, an institute he helped to set up.

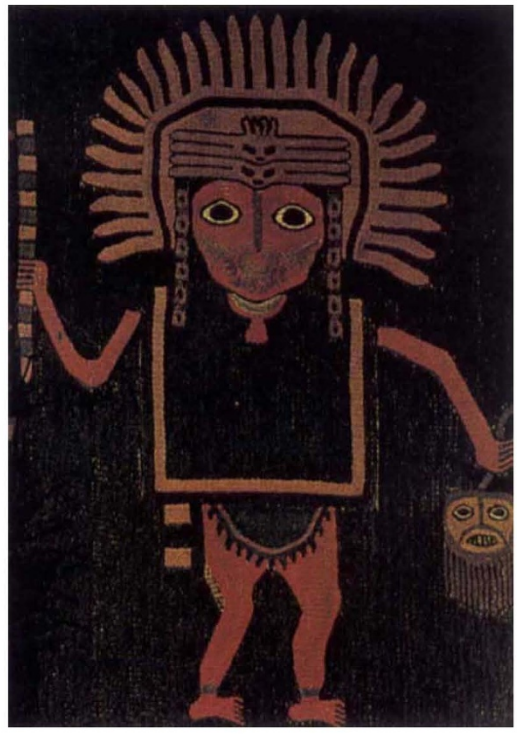
An immediate difficulty, at the lowest level of the chain of connections, is with the interpretation of quantum mechanics. A jaguar is a unique, persisting and well-defined classical object, whereas an elementary particle is a quantum object, identical to its companions, transitory and with properties that depend on how it is observed. Gell-Mann's view, extensively developed by many people over several decades and admirably described here in a nontechnical way, is that a classical history emerges by summing over all the quantum possibilities compatible with it. This is 'coarse-graining'; and the sum, over the 'fine-grained' alternatives, induces 'decoherence' that eliminates the interference phenomena (for example, between the live and dead Schrödinger cat) at the root of all characteristically quantum effects. On this view, with which I agree but which is controversial (although Gell-Mann does not emphasize the fact), there is no need to supplement quantum mechanics by, for example, adding nonlinear terms to the Schrödinger equation. As a treatment of the classical limit it is, however, incomplete, because it rules out of consideration the subtle and intricate emergent phenomena, now being discovered, that occur in systems whose environment is so well controlled that decoherence does not happen.

A classical world is of course far from a living one; indeed, the alleged sterility of the deterministic world of Newtonian bouncing balls is often contrasted with the changing richness of the natural world. A central concept in understanding the latter is the 'complex adaptive system', which "acquires information from its environment . . . identifying regularities in that information, condensing these regularities into . . . a 'schema', and finally acting in the 'real world' on the basis of that schema". Gell-Mann gives a careful discussion of the various sorts of complexity, starting with chaos (that is, unpredictability arising from dynamical instability, so that initially neighbouring trajectories develop very differently). Closely related is the algorithmic complexity of a sequence of symbols, defined as the length of the shortest computer program that could generate it. These ideas are intended to describe the absence of order, and fail to capture the intimate blend of structure and randomness in a complex adaptive system. For this, a better concept is effective complexity: "the length of a concise description of the regularities of [a] system". There is much discussion of how the high effective complexity of a complex adaptive system could arise as an emergent phenomenon, from simple rules acting over a long time.

In the final chapters, there is a sudden shift away from science, with a discussion, in a voice "as much that of the advocate as of the scholar" of the principles that should govern transitions to a world where human activity preserves and sustains a diversity of species and cultures. Although I have some sympathy with Gell-Mann's opinions, I find his arguments less compelling than the rest of the book. For a start, there is the fundamental question of why it is good to preserve diversity. He asks: "Does it make any sense to destroy . . . [what] evolution has built up over such a long period?" But (as he mentions) this has happened before, for example at the end of the Cretaceous period, and the eventual result was more diversity, including us. By inhibiting our 'natural' destructiveness, could we not be committing the ultimate 'speciesist' crime of preventing the emergence of organisms more effectively complex and adapted — in a word, better — than us? And is it desirable to preserve cultures with values (such as intolerance and expansionism) incompatible with our own? Gell-Mann recognizes this difficulty but has nothing new to say about it.

As well as the thoughtful exploration of its main themes, the book contains many insights into superstition, pseudoscience ("the dissociation of belief from evidence") and scientific creativity, and a great deal of wry and engaging humour. □

Michael Berry is in the H. H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK.



THIS decorative cloth, from the third century BC, was found in the desert near Pisco, 125 miles south of Lima. The picture is taken from *The Land of the Incas*, first published in 1977. The book contains more than a hundred spectacularly beautiful photographs by Hans Silvester of the landscape, archaeology and people of the region, together with a short introduction to the Inca empire by Jacques Soustelle. Thames and Hudson, £12.95 (pbk).