

The Quark and the Jaguar: Adventures in the Simple and the Complex

Murray Gell-Mann and David Park

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is rather diffuse. Many of the articles are, in themselves, interesting and persuasive; but the book as a whole does not provide (nor does it seek to provide) a balanced or comprehensive analysis of Popperian philosophy. Philosophers seeking new insights into the idea of methodology, theories of history, the concept of a scientific revolution, or the relation between Popper's philosophy and contemporary theories of knowledge will find plenty here to keep them occupied. Some of the contributors offer detailed analysis of particular problems in Popper, while others use his general philosophy as a jumping-off point for the development of their own ideas; and the fruits of both approaches will be of considerable value to those working in the field. However, the "general reader" seeking a broader understanding of Popper's theories, and of the reasons why philosophers have been hostile to them, will get less out of it.

Newton-Smith is, I think, right to argue that many followers of Popper do not take his theory seriously enough. Popper's writing is undoubtedly engaging—*Conjectures and Refutations* (Routledge, London, 1963) and *Objective Knowledge* (Clarendon, Oxford, 1972) both contain good statements of his central arguments—but it is surely wrong to endorse any theory without giving at least some thought to its consequences and to the criticisms offered by other philosophers. In this respect one would certainly profit by reading *Karl Popper: Philosophy and Problems*, but I think that there are other works which provide a more coherent view. Two books which seem to me to provide such a view are Newton-Smith's *The Rationality of Science* and Anthony O'Hear's own volume on Popper in the Arguments of the Philosophers series (Routledge, London, 1980).

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The Quark and the Jaguar: Adventures in the Simple and the Complex. Murray Gell-Mann. 392 pp. W. H. Freeman, New York, 1995. Price: \$23.95 (cloth) ISBN 0-7167-2581-9; \$15.95 (paper) ISBN 0-7167-2725-0. (Reviewed by David Park.)

If one of the criteria that distinguish a good book is that it helps you to change the way you think, then Murray Gell-Mann has written a good book. It consists of four long essays whose common theme, though they sometimes travel rather far from it, is announced in the Prologue. Here we are introduced to "complex adaptive systems," examples of which would be the reader or some other animal or a community of interdependent animals or a child learning to talk. It seems to be a fact that the physical laws which govern quarks, of which all members of any species are exactly alike, are also responsible for the individuality, the capacity to adapt and learn, of a complex adaptive system, and in Part I, dealing with concepts of complexity, randomness, and organization, the author begins to study how this fact can be understood.

Part II, the Quantum Universe, is concerned with superstrings and the standard model and also presents a contemporary view of quantum mechanics. I will enlarge on this a little. The section starts out with the conviction that the proper business of quantum mechanics is to tell how things

actually happen, and not merely how they appear to a particular observer, and one, moreover, who has the patience to endlessly repeat the same experiment. The view that is being developed by Gell-Mann and James Hartle, along with Roland Omnès, Robert Griffiths, and several others, is based on the idea of a quantum history as represented by a path integral. It is assumed that we understand what probability is and that events in the world of our experience have probabilities associated with them. Probabilities are additive, but where histories interfere one must add amplitudes instead, and therefore one cannot assign probabilities to them. In the famous two-slit experiment (which physicists often claim not to understand) it is impossible to assign a probability to a history that starts at the source, passes through slit A, and reaches the screen at point P. But entangle that history with that of some system that interacts with it, for example an efficient counter, and sum over microscopic states corresponding to the counter's indistinguishable macroscopic states. Now probabilities can be assigned, but of course the interference pattern has disappeared. This illustrates one of the ways in which, by coarse-graining, a history can be defined roughly enough so that its interference with other histories is as small as desired and it acquires a probability. And thus, without introducing observers or classically described laboratory apparatus or "letting \hbar approach zero," we can recover our ordinary experience of the world, embodied in classical physics, as a limit of quantum physics.

Coarse-grained histories are affected, sometimes in important ways, by fluctuations; a fluctuation can produce branches in a history (each with its appropriate probability) that persist after cross-graining and may even affect things on the scale of our experience. A coarse-grained history tends to have the form of a tree, and now at last comes a job for that "information gathering and utilizing system" that the Old Masters called an observer. Armed with a hatchet, it prunes the tree of histories, removing branches that might have happened but did not, a procedure distantly analogous to the collapse of the wave packet but here a matter of mental organization that is in no way a physical process.

Part III is called Selection and Fitness, and it starts with the idea of a coarse-grained history in which there has been a fluctuation large enough to produce a departure from classical behavior. Gell-Mann calls such departures "frozen accidents," and it is with this concept (or metaphor?) that he turns to a discussion of biological evolution. The general direction of evolution is governed by fitness, and he vividly illustrates the process with the concept of a fitness landscape, here imagined as a two-dimensional display of possible characteristics in which some measure of fitness, pointless to specify clearly, is plotted so that fitness increases with depth; a specially fit collection of attributes here corresponds to a local minimum, what is called a "basin of attraction" in dynamics. It is easy to imagine an organism evolving through a series of frozen accidents so as to sit in the minimum, but what then happens to the evolutionary process? And what of the unlucky organism that settles into a shallow basin when there is a deeper one nearby? Considered as a complex adaptive system, a species functions best in the presence of noise, of accidents that tend to keep it from settling down. Coelacanth and cockroach must each survey the world from a deep and quiet basin.

Part IV, Diversity and Sustainability, considers the future of animal species and human cultures and the earthly environment. Each is a complex adaptive system, and Gell-Mann

tells how the Santa Fe Institute, which he helped found, seeks ways of thinking and computation that permit rational analysis of structures built up of such systems. The aim is not to solve the problems that face humanity—the best is the enemy of the good—but to learn how to make arrangements that tend toward states in which things do not get any worse.

The four essays of *The Quark and the Jaguar* can be read independently with little sacrifice of understanding. Reading gets easier as one adapts oneself, unaided by any mathematics, to the precise and didactic tone. The scope is wide, the vision is vast. Occasionally there is an epiphany, a glimpse

of the jaguar's tail. Murray Gell-Mann's book leaves me recalling a couplet from Schiller's *Sonnets to Confucius* that was a favorite of Niels Bohr's:

*Nur die Fülle führt zur Klarheit,
Und im Abgrund wohnt die Wahrheit.*

David Park is Professor Emeritus of Physics at Williams College. His new book, The Fire Within the Eye, essentially a history of light, will be published by Princeton University Press in 1997.

THE PLEASURE OF DISCOVERY

You will find much greater pleasure in gathering from a book a single hint which you afterwards expand and develop into a theory than in transferring from a book into your own mind in all its propositions a general theory. Nothing is of more importance to the healthy growth of the mind than the constant habit of attempting to resolve for itself the phenomena presented to it. We may find that our solutions are the same as those long known to the world but this does not deprive us of the pleasure of the discovery. They are original with us and we feel for them the interest of paternity.

It is astonishing how the mind of an ordinary individual may be improved by a process of this kind and how a subject will expand by keeping the attention steadily directed to it for a length of time. At first all may appear dark but at length light breaks in upon it, the twilight is succeeded by the morning and the morning by the perfect day.

Do not attempt too much at first if your mind is slow in its operations. Narrow the field of view until you bring the number of objects within the scope of your mental vision.

Joseph Henry, "Closing Remarks for Natural Philosophy Course" (1846), in *The Papers of Joseph Henry*, edited by Marc Rothenberg (Smithsonian Institution Press, Washington, 1992), Vol. 6, p. 415.

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