The Dreams of Reason: The Computer and the Rise of the Sciences of Complexity by Heinz R. Pagels. (Simon & Schuster, 1988).

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> Science has explored the microcosmos and the macrocosmos; we have a good sense of the lay of the land. The great unexplored frontier is complexity.
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> —Heinz Pagels, *The Dreams of Reason*

Two of the most remarkable developments of twentieth-century science have turned out to be inextricably linked: the invention (and truly meteoric ascent) of the electronic digital computer, and the unfolding of a new group of scientific efforts aimed at discovering the laws governing physical, biological, and cultural systems of enormous complexity. What these efforts are, and how the computer has shaped them and the new world view they are producing is the subject of physicist Heinz Pagels' last book, *The Dreams of Reason*. Pagels, whose research made significant contributions to a number of areas in physics, was not only a highly prominent member of the scientific community—serving both as an associate professor at Rockefeller University and as Executive Director of the New York Academy of Sciences—but was also a prolific writer of books and articles on science for the lay public, as well as a committed campaigner for human rights around the world. Pagels' distinguished career ended tragically when he died in a mountaineering accident in Colorado in 1988, the same year *The Dreams of Reason* was published. This book, perhaps more than any of his other popular works, demonstrates the extraordinary range of his scientific and philosophical interests, and the degree of excitement he felt about new developments at the frontiers of science.

Pagels' purpose in writing this book was no less than to prepare the world for the coming revolution brought on by the new-found abilities of science to tackle and master complexity. He writes, "I am convinced that the nations and people who master the new sciences of complexity will become the economic, cultural, and political superpowers of the next century. The purpose of this book is to articulate the beginnings of this new synthesis of knowledge and to catch a first glimpse of the civilization that will arise out of it."

The "new sciences of complexity" include both novel approaches in traditional disciplines such as economics, neuroscience, psychology, and biology, and truly new areas of research that do not fit easily into established scientific boundaries, such as artificial intelligence and cognitive science, chaos theory, and artificial life. The three main themes of the book, at least as promised in the Introduction, are the rise of these new sciences and the synthesis that they are providing; the role of the computer in the development of these sciences; and the effects of the resulting reordering of knowledge on long-standing philosophical questions. I found the prospect of such a book very exciting indeed; at this point in the development of the sciences of complex systems, nothing is needed more than a clear framework for thinking about how these various systems are related and how computers are being used to gain insight into the workings of and relations among such systems. However, though the book contains much that will be of interest both to scientists and to lay readers, I found the overall result disappointing.

The book is in two parts, the first on "The Sciences of Complexity" and the second on "Philosophy and Antiphilosophy". The two parts seem almost entirely unconnected, as though two separate books were bound together.

Part I consists of a survey of some of the main ideas in the study of various complex systems, and of some of the major ongoing research efforts. In these chapters, Pagels discusses what he sees as the main themes underlying all these efforts: the use of biological organizing principles, such as variation and selection, in understanding systems in different disciplines; an emphasis on parallel networks as a unifying framework for complex systems; the importance of nonlinear dynamics and chaos in thinking about complex systems; a *computational* view of mathematics and physical processes; and the notion of the computer as a new way of probing natural systems, extending the traditional "theory" and "experiment" division of science. Pagels has done well in choosing these general themes to explain what the sciences of complexity are all about, but the book manages to treat these themes only at a fairly superficial level.

For example, a major theme is that the computer "is altering the architectonic of the sciences and the picture we have of material reality". This is happening in two ways: computers are being used as modeling or simulation tools that provide views of complex systems that could not be easily obtained through direct experimentation on the real systems, and also the notion of *computation* itself is being adopted as a principle for understanding the laws governing such systems. Pagels discusses these two notions and gives some examples, but the book tends to favor breadth over depth, and does not go very deeply in explaining what these two notions actually mean. This is disappointing, because these are very subtle ideas that need careful explanation. The notion of a *computer model* is absolutely central to modern science, and yet what a computer model is, what a mathematical model is, how they are different, and how they might produce different insights, remain obscure to most lay readers, for whom I assume this book was intended. The book contains many intriguing statements such as "Computers, because of their capacity to manage enormous amounts of information, are showing us new aspects of social reality", but never goes much deeper than that in describing *what* new aspects are being shown, and *how*.

What the book lacks in depth in its discussions of these issues, it makes up for in breadth. Pagels covers a very wide range of interesting topics, though in a somewhat disjointed way. The first chapter of Part I is an overview of the main themes of the book. We are then taken at lightning speed through a survey of different attempts at defining the notion of "complexity", and then through nonlinear dynamics and chaos theory, from which we jump to an overview of several different computer simulations of complex systems, after which a chapter is devoted to discussing connectionism and neural nets (in somewhat more depth than is devoted to the previous topics). (Throughout Part I there are several mentions of the Santa Fe Institute and SFI-affiliated scientists.)

This book is obviously the work of a highly diverse mind. Within the space of a few pages, Pagels can jump from selective systems as a bridge between disciplines, to selfish genes, to sociobiology, to problems in synthesizing biology and social sciences, to artificial life. None of these topics is given much more than a paragraph or two, and it is often hard to keep up or to get a clear sense of any of these issues if one doesn't already know much about them. I enjoyed the range of the book, but was constantly frustrated by the lack of depth. There are many tantalizing throwaway lines, such as the following: "But in fact, nature can be viewed as an analogue computer." Or, because of the notion of "selective systems", "...it may, in fact, now be possible to develop a science of society that is minimally distorted by the political and social values of the investigating scientist much as is the case in the natural sciences." Or, "Chaos isn't just a meaningless jumble. In fact, it may be possible to detect the statistical regularities in chaos provided that chaos is used as a probe." These remarks are suggestive, provocative, and demand further explication, but often we are left hanging on the edge of our seats. I found myself constantly wishing that *more* would be said on a particular topic, but was hardly ever satisfied. In general, too many topics are covered at too superficial a level.

The second part of the book (which seems almost like an entirely different book) is a collection of essays on various philosophical issues that are related to modern science, such as the mind-body problem, the nature of mathematics, and the characterization of scientific activity. The title of the book doesn't really apply to Part II, since these essays do not directly bear on computers or complex systems. There is, however, much of interest here, for those who enjoy thinking about classic philosophical questions such as "Are mathematical objects *real*?" or "What is the nature of consciousness and free will?" Pagels combines a survey of philosophical thought on these questions with his own musings, anecdotes, recountings of conversations with friends and neighbors, childhood reminiscences, etc. The style is quite rambling, disjointed, and somewhat repetitive—this book is not strong on crisp organization or on sticking to a point—but these essays are nonetheless fun to read, often very thought-provoking, and sometimes rather irreverent. Much of Pagels' obviously strong personality shines through, as in one anecdote that will raise many hackles: He almost gleefully reports expressing the following opinion (that resulted in shocked silence) at a party with a number of writers, editors, and other intellectuals of humanistic bent ("not a scientist in the group except for me"): "It is difficult for me to remember people's opinions (even my very own). What I remember are concepts and facts, the invariants of experience, not the ephemera of human opinion, taste, and styles. Such trivia are not to be considered by serious people, except as intellectual recreation."

Throughout Part II is the theme of Pagels' strong belief in the reality of the referents of scientific theories: "The invariant order of nature that is expressed in our theories—the cosmic code—is possible because the material world is actually organized in that way." He is clearly very interested in philosophical questions about whether or not scientific theories are discovered or invented, and while he attempts to reconcile these two views, he comes down squarely on the side of discovery: "This is perhaps the most socially and culturally distinguishing feature of science – it is universal in the sense that its truths are truths for *everyone*."

What does all this philosophy have to do with complex systems and computers? Connections between Parts I and II of the book are not made, at least not very clearly. The second-to-last chapter, with a fairly brief discussion of scientific instruments and how they affect science, finally comes back to the computer, saying once more, "The computer, the instrument of the sciences of complexity, will reveal a new cosmos never before perceived", but does not go into much detail about how it will do so. A clear account of the many ways in which computers and the sciences of complex systems have been fundamentally linked, and how this has changed (and will change) the way scientists think was what I was most hoping for in this book, and though the book was enjoyable and stimulating in many ways, this hope was ultimately unfulfilled.

But in spite of the imperfections and the often frustrating lack of depth, I would recommend this book for those who want a broad overview of the frontiers of complex systems research or an introduction to some of the major questions in philosophy of science and mathematics. There is much here that will provoke any reader's interest, and will leave one wanting to learn more. *The Dreams of Reason*, along with his other books and articles, serve as a legacy of Pagels' broad interests and commitment to sharing his tremendous excitement about science with the general public.