and Detroit, was sued by the Environmental Protection Agency for its failure to clean up its waters. Although the suits were settled, the fact remains than an industrial city the size of Atlanta puts an enormous burden on the sewage absorption capacity of a river the size of the Chattahoochee no matter how advanced its treatment facilities are.

Whatever its flaws, however, the study merits attention. It is a pioneering attempt that offers much promise. Indeed the chapter by Caulson presents a methodology that is useful and adaptable to the purpose for which it was intended. Moreover, even if not all the chapters are presented, as promised, in quantifiable terms, they contain some interesting qualitative material. If nothing else, this is a useful handbook of regional environmental efforts. It also shows how existing material prepared by organizations such as the Environmental Protection Agency and various regional government groups can be utilized in a creative way.

The comparative nature of the study leads to some noteworthy observations. While big cities with their greater waste disposal loads are likely to have more serious environmental problems than small cities, they need not have if their authorities exercise enough foresight. Thus waste disposal in Los Angeles is more successful than it is in many smaller American cities. Conversely smaller cities, like Savannah, Georgia, and Green Bay, Wisconsin, can have very serious water problems if they have had the misfortune to attract polluting industries.

Van Tassel points out that, wherever they can, large cities try to export their waste (Chicago sends its water down the Illinois River) and import the resources they need so as to transfer their environmental burdens to other places. New York imports its water from upstate, and Los Angeles its electrical energy from the Four Corners. Observations of this sort do much to enliven the volume.

Finally, the difficulty students had in quantifying the environmental future of some regional air and watersheds, because of both the unavailability of data and the unpredictability of technological and human development, suggests how fragile prediction for the country at large must be.

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Population Dynamics

The Mathematical Theory of the Dynamics of Biological Populations. Proceedings of a conference, Oxford, England, Sept. 1972. M. S. BARTLETT and R. W. HIORNS, Eds. Academic Press, New York, 1973. xii, 348 pp., illus. $21.50.

In his graceful introduction to this collection of conference papers, Coulson writes: "The mathematician needs the restraining hand of the experimental biologist, and the biologist needs the rigorous competence and analytic power of the mathematician. Without this mutual interaction we have all too often bastard mathematics or 'sloppy' biology. Nowhere is this more clear than in the study of population dynamics: nowhere is it more necessary to establish an effective liaison." The fostering of such a liaison was the aim of this conference, held under the auspices of the (British) Institute of Mathematics and Its Applications, in association with the Institute of Biology.

The papers are grouped under five headings: Population Processes in Time (mainly simulation of fisheries); Population Processes in Space; Population Genetics (the most mathematically sophisticated section); Estimation and Simulation Problems (largely mark-recapture methodology); and Population Distribution and Community Structure.

The first chapter is a crisp survey of "Equations and models of population change" by Bartlett. Formal and telegraphic in style, and equipped with a good bibliography, this chapter will be useful to a mathematician seeking a signposted entry to the literature. Bartlett emphasizes problems involving stochastic processes, and makes no mention (except in the bibliography) of models involving competition, predator and prey, patterns of species distribution and abundance, or community structure. This by and large sets the tone of the book. Another notable paper is by Skellam, who lucidly discusses the way diffusion equations may be used to describe invasions, seasonal migrations, and other movements of biological populations. Williamson gives a constructive review of the baroque literature on measures of species diversity, and argues for the need to go beyond such static measures of diversity to study the ebb and flow of interacting populations.

Most of the senior mathematicians deployed at this conference have their background in mathematical statistics. This is indeed the branch of mathematics relevant to most of the papers in the collection: for example, those on population genetics (Bodmer, Karlin, Robertson, Hiorns), technical aspects of mark-recapture methods (Cormack, Bishop and Sheppard), epidemiology (Bailey), spatial patterns in host-parasite relations (Pielou), statistics of cell proliferation (Macdonald), and stochastic formulations of life tables (Gani). However, there remain many central problems in theoretical population biology where the tools of classical applied mathematics, or even of electrical engineering, are likely to be more helpful than those of mathematical statistics: for example, problems concerning energy flows in, and other dynamical aspects of, food webs; or in the theory of the niche; or in comparatively realistic models of host-parasite systems. These areas are essentially unrepresented in the collection, the exceptions including some interesting but specialized simulation studies, Murdie and Hassell's elegant laboratory study of predators' searching behavior, and the contributions of Skellam and Williamson mentioned above. Overall, I have the impression that the conference was organized by first selecting good people, and letting their interests dictate the choice of topics, as opposed to first agreeing on a balanced program reflecting the broad sweep of "the mathematical theory of the dynamics of biological populations." The former strategy is of course sound; it has produced a strong book of limited scope.

These general observations may be illustrated by some specific instances.

The chapter by Jones and Hall includes numerical simulations that explore the dynamical consequences of various assumptions about egg production and recruitment in fish populations. The authors make the empirical observation that such simulations can show stable patterns of periodic oscillation, and they give a perceptive discussion. It is noteworthy that apparently no one at the conference was equipped to point out that their model may be shown, rigorously and generally, to possess stable limit cycle solutions, and furthermore that such stable limit cycles are as ubiquitous and natural in nonlinear systems as are the stable equilibrium points that we learned to love in elementary (linear) mathematics and physics courses.

One crass, but usually reliable, way to form a view of a book is to look at the author index. The text contains *no* reference to MacArthur, Levins, or

Hutchinson (although MacArthur and Levins get a citation in Bartlett's bibliography). And if Murdie and Hassell's paper be excepted, the volume contains no reference to so diverse an array of people as Lotka, Volterra, Nicholson, Bailey, Watt, Holling, Odum, and Margalef. (The population geneticists, on the other hand, seem to have their Canonical Citation Abundance Distribution.) I could play a similar game with the subject index, but as the index is itself a bit capricious this would be cheating.

In short, this is a collection of interesting papers, including some useful reviews and some examples of mathematics well integrated with biology. In addition, the book serves a constructive purpose as an unconscious—and therefore all the more reliable—indicator of the strengths and (by omission) weaknesses of theoretical population biology in Britain.

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Philosophical Problems

The Many-Worlds Interpretation of Quantum Mechanics. A Fundamental Exposition. BRYCE S. DEWITT and NEILL GRAHAM, Eds. Princeton University Press, Princeton, N.J., 1973. viii, 253 pp. Cloth, $12.50; paper, $5.50. Princeton Series in Physics.

This book is a collection of papers concerned with the philosophy of quantum mechanics, and in particular the many-worlds interpretation of quantum mechanics. There are seven articles in the collection, the first by far the longest. I recommend to readers that they begin with articles 4, 3, and 2, in that order; they are not very lengthy and contain the heart of the material.

Philosophies of quantum mechanics are very personal matters; I approach this question as one who received a traditional physics education during the '50's and has been a practicing mathematical physicist ever since. By chance my personal view of quantum mechanics is close to that propounded in this book, here called the many-worlds interpretation. Preliminary to writing this review I recalled in my mind my past thoughts on the philosophy of quantum mechanics, and numerous past discussions with other physicists. I also undertook a casual survey of many of the other physicists at my present institution. It seems safe to say that the new breed of physicist has not thought much about philosophy, and feels that such questions of interpretation are irrelevant to his research. This insouciance is present to such an extent that certain misconceptions are commonly held, which I shall return to later. I would be among the last to urge scientists to read about interpretation of quantum mechanics as an aid to research. For those students, scientists, philosophers, and scientifically learned nonscientists who are in the process of puzzling about the connection between quantum mechanics and reality, I recommend the present book. If one wanted to read one and only one book on this subject—not at all a bad idea—this is a good book to read. We proceed to a brief discussion of the many-worlds interpretation.

In quantum mechanics a system is described by a vector (wave function) in Hilbert space, the time development of the system described by the time dependence of the vector. The vector in Hilbert space generally is a probability distribution for an infinite number of classical states of the system. Speaking simply, then, quantum mechanics can provide only a probability for a given occurrence, and not a deterministic prediction of a fixed outcome. Thus quantum mechanics is not a physical theory by the criteria physicists used to insist on. Einstein, for example, could not reconcile himself to it. At the opposite extreme, the prevalent view today is that a calculation of probabilities is all we ask of science.

One's first efforts to reconcile oneself to quantum mechanics often begin with the assumption that the wave function (vector) of the universe might be so peaked about a single classical state that the classical universe we live in could have its motion deterministically predicted by the wave function. Many physicists suffer this harmless delusion. As is discussed in the fourth article of the collection, the *Gedanken* experiment with Schrödinger's cat convinces us that this is impossible. Classical events, such as whether the cat lives or dies, or whether you buy this book or not, can be affected by quantum-mechanical-scale events. In the wave function of the universe—if one accepts quantum mechanics to this extent—there is a nonzero probability that you buy the book and a nonzero probability that you do not. There are two common philosophies to reconcile one with this unpleasantness, the Copenhagen view and the many-worlds view.

The first view essentially is that quantum mechanics is wrong. The equations are to be modified in some way so that the wave function always is peaked about a single classical state. Some mechanism "collapses" the wave function to a function peaked at a single classical state whenever it would "split" into a function peaked at a number of "classical" alternatives. There is a distinction, obscure to me, made between looking for a specific modification of the equations and merely postulating the "collapse." It should be emphasized that in any case such modification of quantum mechanics is real and would affect the results of experiments and calculations, although in a negligibly small way for realistic experiments.

I was one of those who embraced quantum mechanics bra, ket, and matrix. I believe there is a wave function of the universe satisfying some linear evolution equation, so I am in the many-worlds camp. The wave function describes a continuous infinity of classical states developing in time, "splitting" and "recombining"; God runs his finger along the function picking out our actual world. Hugh Everett III, in the second paper in the collection, has formalized such an interpretation of quantum mechanics. There is a continuous infinity of classical worlds coexistent at any time; we are in one nonexceptional member of this set. Although, as authors in the collection say, this seems "bizarre" and is "startling," in fact, it is the natural interpretation one is inescapably led to if one takes the view that quantum mechanics is the ultimate formulation of nature's laws; the universe is a vector in Hilbert space.

To those who immediately reject the many-worlds view in favor of the Copenhagen view, one should recall that the Copenhagen view has its own difficulties. All the processes that make up a classical object are described by quantum mechanics, but not the object itself. There is no natural scale at which objects become classical: When does the wave function collapse? How can one modify quantum mechanics to correctly collapse? Since the many-worlds view requires quantum mechanics and nothing more—no "collapse," no "hidden variables," no "classical observers" —it is the most conservative interpretation. The fact that most books on quantum mechanics do not present this view makes this book a desirable addition to