selection is surely a dominant theme in the evolution of all sexual organisms.

Eberhard also makes a compelling case for a reformation in reproductive physiology. No one following his arguments can ever again suppose that physiology and anatomy have evolved solely to maximize the chances of fertilization. The lesson seems clear: physiology must become evolutionary if the intricacies of reproductive systems are to be fully understood. This book should provide fertile reading for every reproductive physiologist as well as every evolutionary biologist. For others, just the descriptions of sexual intricacies will command attention.

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The Dynamics of the Seas

Ocean Circulation Theory. JOSEPH PEDLOSKY. Springer-Verlag, New York, 1996. xii, 453 pp., illus. $89.95, £60, DM 128, or FF 483. ISBN 3-540-60489-8.

The Ocean Circulation Inverse Problem. CARL WUNSCH. Cambridge University Press, New York, 1996. xiv, 442 pp., illus. $54.95 or £35. ISBN 0-521-48090-6.

In response to the great interest in the global environment a large number of excellent undergraduate textbooks have appeared in recent years. By contrast, there are relatively few books available for advanced students preparing to carry out research. So the publication of these two is a major event. Both books are based on courses taught in the Massachusetts Institute of Technology–Woods Hole Oceanographic Institution graduate program, but despite the common origin and similarity in titles there is little overlap in content. Reflecting very different research styles and outlooks on oceanography, the two books complement each other. Both require of the reader the grounding in mathematics expected of research students in the physical sciences, but nothing on a more advanced level.

Pedlosky is the author of an earlier book entitled *Geophysical Fluid Mechanics*, which is an excellent reference book for the basic theory for the dynamics of both the atmosphere and the oceans. Some of the material included in the second edition of that book is included in the new book, but the aim of *Ocean Circulation Theory* is different. A single comprehensive theory for the circulation of either the atmosphere or the oceans is probably not an attainable goal. The motions of the Earth's fluid envelope are just too complicated. On the other hand, a body of ideas on the physics of ocean circulation, which could be called theory, is evolving. In his introduction Pedlosky pays tribute to Henry Stommel, who tried to penetrate the complexity of the ocean circulation by posing simpler problems, illustrating basic mechanisms. Usually these problems could be solved without resorting to complex mathematical analysis or numerical methods. Pedlosky's book is in that tradition, introducing the reader to an up-to-date collection of such problems. Perhaps its most valuable feature is the discussions opening and closing each chapter, which put these simplified problems in perspective and explain their relevance to the real ocean.

The emphasis is on providing insight into the steady-state circulation of the ocean. An atmospheric scientist might be surprised that a separation can be made between the steady and the time-dependent motions, whereas most oceanographers feel entirely comfortable with this idea. *Ocean Circulation Theory* does not attempt a detailed justification of this traditional approach. The book is not intended to be comprehensive, but follows an outline that parallels the historical development of ocean circulation theories. The first few chapters are devoted to models of the wind-driven circulation of the ocean. In these models there is an implicit assumption that a world ocean thermocline exists, and the focus is on how the atmospheric winds acting alone would determine the ocean circulation. Though linear models were first proposed more than 50 years ago, the general, nonlinear form of the wind-driven ocean models has a surprisingly complex behavior that is the subject of continuing research by numerical methods. A strong point of the book is a detailed review of this research, which includes results obtained in the last few years. This is the only section that discusses numerical results in detail, although numerical results for thermocline models are cited and compared with analytic results in later chapters.

A large section of Pedlosky's book is devoted to analytic models that illustrate how wind and buoyancy forcing shape the thermocline. The author not only discusses his own research but devotes a major portion of the book to the preceding work of Rhines and Young on quasi-geotrophic models. Anyone interested in learning about thermocline theory will find this readable account a valuable alternative to tackling the original research papers directly. The presentation allows the reader to understand the historical development of ideas and shows the observational data that motivated the thermocline models.

Wunsch's *The Ocean Circulation Inverse Problem* has an entirely different focus. Wunsch has been a pioneer in adapting statistical methods from other scientific fields to oceanography. Rather than describing models or theories of the ocean circulation, his book aims to provide the reader with the statistical tools to test the validity of simple models with oceanographic observations. The book assumes knowledge of only the most rudimentary measures of statistics, and a large portion of it is devoted to introducing statistical inverse procedures and illustrating their application to very simple one- or two-dimensional models. All the mathematical development is devoted to discrete rather than continuous systems. This involves a rather heavy use of matrix algebra, but overall it provides concreteness and consistency. The emphasis is not just on fitting a model to data but on determining the quality of the fit, which is often quite difficult for large data sets and complex models. Further chapters are devoted to much more detailed examples, drawn largely from the research of the author or his students, of fitting models to data. A tremendous fund of experience is distilled in this book, with emphasis on pitfalls in the application of inverse methods. This is still a very young field, and most of the models discussed are too simple to really make use of the dynamic constraints of the full equations of motion and continuity. Little experience has accumulated as yet on the application of inverse methods to numerical global ocean circulation models, but the treatment in this book suggests how it might be done. The book has a very complete set of literature citations, making it a useful reference book as well as textbook.

Thanks to initiatives and programs led by Wunsch and others, the quantity of data on the ocean circulation is increasing rapidly. The powerful computers needed to analyze this new stream of data are becoming available as well. The study of ocean circulation is moving out of its exploratory stage to a new stage of quantitative modeling with applications to marine biology, geochemistry, and climatology. Both these books offer valuable guides for this new era of oceanography. Pedlosky's will be an invaluable aid in interpreting the solutions of the new global models, and Wunsch's will provide the tools for checking the models against the real world.

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