some technical background, is interested in the subject, and wants a fascinating introduction to the field. I would particularly recommend it to researchers for its scholarly historical presentation and to students for its effectiveness as a great learning aid.

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Ocean Biogeochemical Dynamics

Jorge L. Sarmiento and Nicolas Gruber
Princeton U. Press, Princeton, NJ, 2006. $75.00 (503 pp.).
ISBN 978-0-691-01707-5

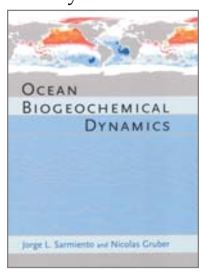
In *Ocean Biogeochemical Dynamics*, Jorge L. Sarmiento and Nicolas Gruber have succeeded in providing students and instructors with a remarkably succinct yet complete account of current ocean biogeochemistry. The authors are both experts in the field who have long records of distinguished contributions. The central objective of *Ocean Biogeochemical Dynamics* is to unravel the nature of biogeochemical and physical interactions that regulate concentrations of elements in the ocean. In meeting this objective, it is admirably successful.

The book begins with a summary of the elemental composition of today's oceans. It relates the concentration of elements to the rates at which they are supplied by rivers. Concentrations and rates of supply are used to calculate the residence times for individual elements to accumulate in the ocean. Sarmiento and Gruber point out that elements such as sodium and chlorine, with residence times measured in tens of millions of years, are distributed more or less uniformly throughout the ocean. For elements with much shorter residence times—carbon, nitrogen, phosphorus, and iron, for example—the spatial distribution is more complex. In many cases the complexity reflects the influence of either the uptake or release of elements by biologically mediated reactions.

The overarching challenge of the book, unstated but clear in retrospect based on the emphasis of the final chapter, "Carbon Cycle, CO_2, and Climate," is to understand the complex factors that regulate the distribution of carbon dioxide in equilibrium with surface ocean water. The book examines the spatial and temporal variability of that equilibrium and ultimately the role equilibrium plays in determining the concentration of atmospheric CO_2, not just for the contemporary environment but also for the recent and more distant past.

Carbon is present in ocean water in various forms: as dissolved hydrated carbon dioxide (H_2CO_3); as bicarbonate ion (HCO_3^-); as carbonate ion (CO_3^{2-}); as organic matter, particulate and dissolved; and as calcium carbonate ($CaCO_3$). The distribution of carbon among the principal inorganic species, H_2CO_3, HCO_3^-, and CO_3^{2-}, and the corresponding pressure of gaseous carbon dioxide (pCO_2) are determined by considerations of chemical equilibrium. With the total abundance of inorganic carbon and alkalinity, one can readily calculate the value of pCO_2.

The transfer of CO_2 between ocean and atmosphere is determined by the efficiency of gas transfer across the liquid–gas interface and by the difference between the partial pressure of CO_2 in the atmosphere and the partial pressure of CO_2 in equilibrium with the inorganic carbon species dissolved in the underlying ocean water. The book provides an excellent introduction to this mathematically straightforward but intuitively complex topic. It has an excellent account of how and where carbon was exchanged between the atmosphere and ocean in the preindustrial era and how the spatial pattern of exchange differs today from the recent past, especially because of the much greater and ever-increasing concentrations of fossil-fuel-derived CO_2 in the atmosphere.



The authors also include an analysis of the factors that influence the spatial and temporal variations of alkalinity and dissolved inorganic carbon, which is a prerequisite to understanding the carbon exchange of the ocean and atmosphere. Formation of organic matter in ocean surfaces exposed to light is associated with a reduction in dissolved inorganic carbon. Conversion of inorganic nitrate to organic nitrogen leads to an increase in alkalinity that is offset by a decrease associated with production of $CaCO_3$. However, not all of the photosynthetic uptake of inorganic carbon, the production of organic matter, is associated with formation of $CaCO_3$. Diatoms use silicic acid rather than $CaCO_3$ as material for formation of their structural hard parts. What are the circumstances that result in use of silicic acid instead of $CaCO_3$? The issue is complicated and still subject to significant uncertainty, with lingering questions about the possible role of iron in limiting biological productivity over extensive regions of the ocean.

Sarmiento and Gruber's book provides an excellent account of the current understanding of the issues and will serve as an important reference for experienced researchers. It provides background knowledge, specifically a critical appraisal of recent literature, that is needed to stimulate the combination of fresh hypotheses, measurements, and models that define the lifeblood of productive scientific inquiry. The text is comprehensive yet readable, the best treatment of the subject to appear, in my opinion, since the seminal work *Tracers in the Sea* (Eldigio Press, 1982) by Wallace S. Broecker and Tsung-Hung Peng.

Lastly, *Ocean Biogeochemical Dynamics* is a valuable resource for instructors, who will particularly appreciate the problems listed at the end of each chapter, and for graduate students and advanced undergraduates who want to learn more about the chemistry, biology, and dynamics of oceans. I commend it without reservation.

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Out of the Shadows

Contributions of Twentieth-Century Women to Physics

Edited by Nina Byers and Gary Williams
Cambridge U. Press, New York, 2006. $35.00 (471 pp.).
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The first apparatus to measure the surface tension of water. The first observation of nuclear recoil during radioactive decay. The first understanding of the composition of stars. What do these "firsts" in the development of modern physics have in common? All were made by women, and vignettes of their contributions appear in the essays in *Out of the Shadows: Contributions of Twentieth-Century Women to Physics*, edited by Nina Byers and Gary Williams. Does it matter that the discoveries were made by women? The writers of the essays and, in several cases, even the women profiled seem ambivalent on that point.

Byers and Williams have selected 40 women physicists whose work contributed substantially to the development of physics in the century before approximately 1976. Byers is a theoretical physicist and professor emerita at