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

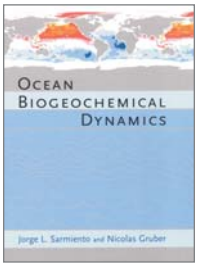
In *Ocean Biogeochemical Dynamics*, Jorge L. Sarmiento and Nicolas Gruber have succeeded in providing students and instructors with a remarkably succinct yet complete account of current ocean biogeochemistry. The authors are both experts in the field who have long records of distinguished contributions. 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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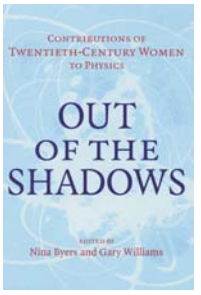
Out of the Shadows

Contributions of Twentieth-Century Women to Physics

Edited by Nina Byers and Gary Williams
Cambridge U. Press, New York, 2006. $35.00 (471 pp.). ISBN 978-0-521-82197-1

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



UCLA; Williams's research is in low-temperature physics, and he is a professor in the department of physics and astronomy, also at UCLA. The physics they cover in the book is quite broadly defined; included are women who have worked in areas as diverse as biophysics, crystallography, geophysics, mathematical physics, cosmic-ray physics, and physical chemistry. Essays are arranged chronologically, and each were written by a practicing scientist or science historian familiar with the specific subject. In several cases the writer is a family member of the woman being profiled. Each essay is divided into three parts: science, biography, and bibliography. It is admirable and distinctive to first cover the stories of important physics discoveries whose provenance has in many cases been forgotten. Yet the book's separation of science from biography may be why several of the essays are redundant in the scientific and biographical parts: The work one does is not neatly separable from the social conditions under which that work is produced. Gender is hardly irrelevant when considering what these particular physical scientists were able to accomplish.

The collection of essays begins with science historian Joan Mason's description of the innovative work of Hertha Ayrton (1854–1923) with carbon arc lamps. Ayrton's groundbreaking text, *The Electric Arc*, was published in 1902, the same year in which the Royal Society "pronounced that a married woman was not a 'person' eligible for fellowship under the Charter" (page 21).

Similarly fascinating is Jean-Pierre Adloff and George B. Kaufman's story behind the discovery of francium in 1939 by Marguerite Catherine Perey (1909–75). It was not until 1962 that Perey was elected to the Paris Academy of Sciences. She was the first woman to be elected; even Nobel laureates Marie Curie and her daughter, Irène Joliot-Curie, had been denied admission. Those facts speak volumes about the attitudinally challenged conditions under which Perey worked.

David Cline's essay on prominent particle physicist Sau Lan Wu, a professor of physics at the University of Wisconsin–Madison, is the final profile in the book. Wu was admitted to Harvard graduate school in 1963, but she was not permitted to enter the men's dorm, where she might have joined her classmates in study sessions. She was the only woman in her entering class. Wu was permitted to attend commencement ceremonies when she received her master's degree the following year; she was not, however, allowed to attend the celebratory lunch afterwards. Tradition simply did not permit such a thing. Despite the affront, Wu returned to Harvard to complete her PhD.

The women described in the essays are nothing if not persistent. Several express reluctance—perhaps necessary to their successes—to dwell on the barriers they faced: Bertha Swirles Jeffreys (1903–99), about whom Ruth Williams writes, "quite emphatically" stated that she would have preferred to be profiled "in a book entitled 'Contributions of *People* to Twentieth-Century Physics'" rather than in one emphasizing work done by women (page 189).

Although barriers to women's work in physics did erode during the 20th century, physics lags behind other sciences in the percentage of women attaining degrees in the discipline. For example, the American Institute of Physics has statistics that show that in 2001 approximately 46% of high-school physics students were female (http://www.aip.org/statistics). Four years later, only about 23% of bachelor's degrees in physics went to women.

As an incentive for young women to pursue physics, and for their instructors to encourage them, *Out of the Shadows* could be more useful in a key area: It needs a collective bibliography. The insights provided by the essayists are crucial in explaining succinctly—occasionally too succinctly—the major accomplishments of each of the women profiled. However, the bibliographies associated with the essays are uneven and generally lack familiarity with the work of historians of science. The book features no women who were born after 1950. Clearly, the question "What challenges are going to face me when I go to graduate school?" did not cease to be relevant for women physicists in 1976.

Students whose interests are piqued by *Out of the Shadows* would benefit from references to other sources, in print and on the Web, that would bring the story of women in physics into the 21st century. The book does cover a lot of ground. Some readers might be surprised to find a few names missing—perhaps Rosalind Franklin, for one; on the other hand, many stories of women physicists whose contributions have not been adequately profiled elsewhere are in the book. Despite its ambivalence in addressing the issue of gender in the scientific community, *Out of the Shadows* is a worthwhile contribution to the overall story of the rise of modern physics.

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On Physics and Philosophy

Bernard d'Espagnat
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Bernard d'Espagnat is well known for his work, principally from the 1970s, on the foundations of physics and his subsequent attempts to construct a philosophical edifice on top of those foundations. If his *Veiled Reality: An Analysis of Present-Day Quantum Mechanical Concepts* (Addison-Wesley, 1995) represents the basic frame of that construction, then his latest book, *On Physics and Philosophy*, can be seen as an elaboration of the galleries and French doors that link the edifice's philosophical rooms and alcoves. Some of those rooms and alcoves are open-sided; others are closed off and apparently lead nowhere.

The first half of d'Espagnat's book surveys the physical foundations, the standard bricks and mortar of philosophical discussions: Bell's theorem, nonlocality and nonseparability, decoherence and de Broglie–Bohm theory, Erwin Schrödinger's cat curling round the feet of Eugene Wigner's friend who performs the famous thought experiment, and so forth. What is missing, however, are the iron rods of mathematical equations. Although the attempt to make the book accessible to a general audience is admirable, the rococo curlicues of d'Espagnat's discursive style snag one's progress through his argumentation. The conclusion that d'Espagnat reaches is that although instrumentalism and idealism are too cheap and thin to be taken seriously as appropriate philosophical attitudes, "standard" realism, with its objective, mind-independent world informed by a classical metaphysics of individual objects and local action, cannot sit comfortably on the piles driven down by the physics. The piles are shaped by entanglement, the concomitant notion of nonseparability, quantum statistics, and the often-drawn implication that