cellular processes, including transcription (writing out mRNA from DNA) and life-cycle events such as cell division and death. Systems biology will eventually need to deal with the systems of systems.

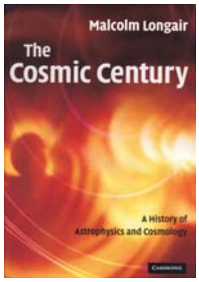
Palsson is a founder of systems biology and he presents an accessible account that is structured in three parts: reconstruction of biological networks from data, mathematical aspects of reconstruction, and results of the approach. Palsson's goal is to model the rate of reactions and the concentrations of the reactants. Without detailed information on kinetic constants, one can nevertheless make progress by focusing on steady states. The challenge is to enumerate what a physicist would call the phase diagram of a biological network as a function of external constraints such as resource availability and other factors, such as biomass generation, that express what biological systems may have evolved to optimize. The end-use of the modeling technique is metabolic engineering: How does a modification to the genome of an organism—by knocking out a particular gene, for example—affect the organism's operating state? Models, Palsson emphasizes, can drive discovery: When systems biology models yield predictions that disagree with experiment, one can pinpoint what aspects of the organism have not been properly represented or modeled. In this way, systems biology helps in the design of experiments that, in turn, lead to better models.

Systems Biology is a very readable introduction to the subject, even though some of the most promising results in the field became available after it had been published. The book's technical level is advanced undergraduate physics or engineering, but a higher level of scientific maturity will be needed to fully appreciate the thoughtful discussions about levels of description and the modeling enterprise in general. There are no exercises, although those will be forthcoming on a website dedicated to the book, according to the author.

Alon's and Palsson's books make it clear that this is an exciting time for biology. The authors expose readers to enough material that the research literature in quantitative systems biology should become accessible. Alon's book should become a standard part of the training of graduate students in biological physics; Palsson's will undoubtedly play a similar role for students of metabolic engineering and perhaps biological physics.

The Cosmic Century
A History of Astrophysics and Cosmology

Malcolm Longair
Cambridge U. Press, New York, 2006. $65.00 (545 pp.).
ISBN 978-0-521-47436-8



Recent advances in physics and astronomy have brought about in our knowledge of the universe a revolution comparable to the one that occurred at the end of the 16th century and through the 17th century during the times of Tycho Brahe, Johannes Kepler, Galileo, and Isaac Newton. Since the first part of the 20th century, we have been able to answer some of the questions that humankind has always asked: How old is the universe, and how did it start? What makes stars evolve, shine, and die? And how do galaxies, planets, and elements form?

However, in the past 50 years the rate of astronomical discoveries has increased rapidly, thanks to powerful new observatories on the ground and in space. The entire range of wavelengths emitted by celestial objects, from radio waves to gamma rays, can now be observed. The data can be analyzed, stored, and distributed by powerful computers. So, what have we found? Perhaps the most striking result is that the universe appears to be filled predominantly with forms of energy and matter different from the normal baryonic matter of everyday objects. What determines the dynamics and the evolution of the universe is subject to natural laws that researchers do not yet fully comprehend. Once again astronomy is posing some of the most fundamental questions for physics.

In *The Cosmic Century: A History of Astrophysics and Cosmology*, Malcolm Longair has written a very timely book, directed toward students, researchers, and lecturers; I enjoyed experiencing all three roles while reading it. It is a lucid and in-depth presentation of the subject and introduces topics at various levels of complexity. *The Cosmic Century* is different from most books on astrophysics and cosmology that are either for the general public or for a specialized audience. The author covers the historical advances in the field with regard to their impact on the astrophysical worldview. In its 16 chapters describing observations and theory, the book takes us through the logical developments and the interactions between data and interpretation. At an even deeper level are the notes and appendixes to the chapters, in which Longair treats specific subjects in greater detail, often with the appropriate mathematics.

Longair is, in my opinion, uniquely qualified to write this tour de force. As a professor of natural philosophy and head of the Cavendish Laboratory at the University of Cambridge, he has conducted significant research in high-energy astrophysics, astrophysical cosmology, and the history of physics. He is a brilliant lecturer and prolific writer. Among his books are *Theoretical Concepts in Physics: An Alternative View of Theoretical Reasoning in Physics for Final-Year Undergraduates* (Cambridge U. Press, 1984) and *Galaxy Formation* (Springer, 1998). He has contributed to some of the major astronomical projects on the ground and in space, including the *Hubble Space Telescope*. His service on many of the committees involved in setting priorities for astronomical research has given him a wonderful insight into how modern astronomy is done and what it may offer as future advances.

Parts 1 and 2 of the book give a very useful account of the progress from astronomy to astrophysics in the last part of the 19th century by introducing the advances in spectroscopy and in the classification of stellar spectra. He summarizes the development of theories of stellar structure and evolution in a manner particularly useful for many physicists who have joined that subfield.

After describing the theoretical and observational advances of the early 20th century, the author introduces readers to modern astronomy in part 3. In this section he narrates with great authority the opening up of the entire electromagnetic spectrum to astronomical observations and the impact of that achievement on the theory of stellar evolution. In addition, Longair covers the physics of the interstellar medium and cluster and galaxy evolution, a subject close to his own research.

The last portion of the book, parts 4 and 5, describes the advances of astrophysical cosmology over the past 50 years—from our knowledge of the origin of the universe, including the development of structure and its evolution, to our measurement of cosmological parameters.

Longair's style very effectively engages the reader in the story of this wonderful adventure of the human mind. I think *The Cosmic Century* would be of great value to anybody who has 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

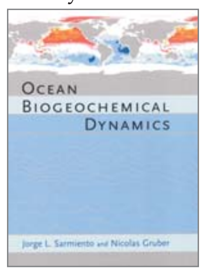
In *Ocean Biogeochemical Dynamics*, Jorge L. Sarmiento and Nicolas Gruber have succeeded in providing students and instructors with a remarkably succinct yet complete account of current ocean biogeochemistry. The authors are both experts in the field who have long records of distinguished contributions.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