his interest in earth science as a teenager and influenced much of his early work. His closeness to his father, a distinguished professor of physical chemistry, was probably important in developing his instinct for applying the principles of that field to geology. The ideas and expertise of the many talented scientists attracted to his laboratories and with whom he worked certainly contributed greatly to his research effort. Moreover, he lived at a time when great discoveries were being made in the basic sciences of chemistry and physics. The most important factor, however, was the man himself. A dedicated hard worker with an encyclopedic memory and a talent for creative thinking, he grasped those new developments in chemistry and physics and almost immediately exploited them for his geochemical research. For example, just six years after Debye and Scherrer developed the powder method of x-ray diffraction in 1917, Goldschmidt began publishing papers on crystal structures determined by this technique in his laboratory. Similarly, the year after Hadding designed an x-ray spectrograph specifically for mineral analysis in 1921, Goldschmidt was using one built in his own laboratory. Although the rapid transfer of new principles and techniques of chemistry and physics to the field of geology was resisted by many North American earth science departments even through the 1960s, this approach pioneered by Goldschmidt has now become ingrained in modern geochemistry, just as undergraduate training in mathematics, physics, and chemistry in addition to earth science, such as Goldschmidt received, has become a prerequisite to graduate study of modern geochemistry.

Mason has skillfully interwoven accounts of these scientific discoveries with details about Goldschmidt's personal life, including his work habits, his sense of humor, his professional rivalries and alliances, and his interactions with family members, friends, and pets. The book contains many excerpts from his personal papers, almost all of which were translated from their original Norwegian, Swedish, or German by Mason himself. Particularly well documented is the gripping story of how Goldschmidt narrowly escaped three separate attempts by the Nazis to deport him to the death camps in Poland along with the rest of Norway's Jews. Appendixes to the book contain memorials written by fellow scientists, a complete bibliography of Goldschmidt's writings, his medical history, a list of his scientific honors, and, for the nonspecialist, tables of chemical symbols and geological time periods and a glossary of technical terms. Profusely illustrated and extensively annotated, most interestingly with brief biographies of his colleagues and acquaintances, this masterly book is a fitting tribute to this towering figure.

"V. M. Goldschmidt and Albert Einstein (in long black coat) at one of the islands in Oslofjord where they were looking at lower Paleozoic sediments. Goldschmidt is holding a specimen(s) which he is in the process of showing Einstein." [From *Victor Moritz Goldschmidt*]

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From Plant to Planet

Scaling Physiological Processes. Leaf to Globe. JAMES R. EHLERINGER and CHRISTOPHER B. FIELD, Eds. Academic Press, San Diego, CA, 1993. xvi, 338 pp., illus., + plates. $69.95 or £56. Physiological Ecology.

One of the most exciting scientific developments of the last 20 years has been the recognition of the fundamental changes in the Earth's atmosphere being wrought by human activities. Climatologists, oceanographers, geologists, computer scientists, and experts in remote sensing envision a forbidding future of global warming, caused by rising levels of carbon dioxide and other trace gases and triggered by the combustion of fossil fuels and tropical forests on an unprecedented scale. Until now, ecologists have contributed rather little to such analyses, even though regional differences in plant reflectance and photosynthesis play key roles in affecting global energy exchange and CO_2 levels.

This volume represents a first attempt by physiological ecologists to show how the leaf-level processes of photosynthesis and respiration might scale up to broader levels and provide a better understanding of global atmospheric trends. Physiological ecologists study how a plant's characteristics help determine its gas exchange, growth, and competitive ability in different environments; such work would be immediately relevant to questions involving global change if the traditional focus on individual plants were shifted to whole communities, landscapes, or continents. This elegant idea is the central theme of this volume, a collection of 20 essays based on a symposium held at Snowbird, Utah, in 1990.

Levin provides a conceptual framework for studying ecological interactions at a variety of spatial and temporal scales. Communities and landscapes are inherently patchy and dynamic; these flickering mosaics exhibit different patterns, processes, and disturbance regimes at almost every scale, and attempts to formulate or understand scaling laws must incorporate such variation. Schimel and his colleagues vividly illustrate this idea by describing the first landscape-scale model for exchanges of energy and matter between the atmosphere and biosphere. In the Flint Hills of Kansas, local and remote sensing techniques were integrated to obtain a picture of heat and CO_2 fluxes over 256 square kilometers of prairies. Habitat patches differed in plant biomass, reflectance, and gas exchange depending on topography, grazing intensity, and fire history. Clouds rolling over the landscape were one of the strongest influences on plant photosynthesis and water loss; cloud formation, in turn, was influenced by the stature, roughness, reflectance, and transpiration of the vegetation carpeting that landscape, suggesting a deep tie between vegetation and atmosphere at the scale of a few kilometers.

Six chapters discuss the problems involved in scaling rates of carbon gain and water loss from leaves to canopies to communities. Norman provides a clear overview of attempts to model canopy photosynthesis, from the "big leaf" analogy, to light-stratified canopies, to complete models involving stratification of light, water vapor, and carbon dioxide with plant feedbacks on each. Eddy transfers of heat and matter within plant canopies are reviewed by Baldocchi. Jarvis and Reynolds *et al.* debate the relative merits of "bottom-up" models for biosphere-atmosphere interactions based on ecophysiology, vs. "top-down" models based on empirical data on mass action at broad spatial scales. Running and Hunt review the successful analysis of carbon uptake and water loss by conifer forests along continental climatic gradients,

Vignette: Opportunities Seized

The road from Kasungu to Mzuzu . . . . passes through the plains and on to the spectacular forests of the Viphya Plateau. Peasant farmers sold sweet potatoes along the road. Boys and girls held out sticks of Malaŵi sausages, dried mice, for sale as lunch to travelers. The mice are caught in the fields by the children. Then they are boiled without much further ado. No skinning, no removing the heads. After boiling, their nice but nubbly little bodies are dried and salted. Half a dozen or so of the stiff sun-dried carcasses are placed in a piece of split bamboo for easy handling. Then they are ready for sale . . . . And for eating—hair, bones, teeth, toenails, and tails—everything.

. . . What a golden opportunity these Malaŵi sausages presented for making a collection of African mouse skeletons that could be used in connection with my fossil-rat interests. Last year I bought every stick of Malaŵi sausages that I could get my hands on. . . . I took all my specimens, for they had now become scientific, back to the Department of Antiquities in Lilongwe. I left them in the office to be shipped to me in Dallas along with some of the season's important fossils. They had not been in Lilongwe twenty-four hours before the staff, thinking I had brought them a treat, ate my entire sample of Malaŵi sausage.

—Louis Jacobs, in *Quest for the African Dinosaurs: Ancient Roots of the Modern World* (Villard)

showing how these can be related to remotely sensed data on leaf area index and how the principles involved can be applied to other biomes. Waring summarizes the potential contributions of ecophysiologists to the scaling of physiological processes to ecosystem function.

Jarvis and Dewar provide an excellent summary of research on the global carbon cycle, discussing the roles played by the combustion of fossil fuels and clearance of temperate and tropical forests, the apparently small sink represented by the oceans owing to slow turnover of deep water, and the large sink represented by temperate and boreal forests in the Northern Hemisphere. More data on forest area and photosynthesis are needed, however. Vitousek discusses how decomposers may vitally affect ecosystem function by setting up positive feedbacks between availability of soil nitrogen and primary production. Although he does not explicitly state it, Vitousek clearly implies that global changes that disrupt such feedbacks could lead to a downward spiral of productivity and further increases in the level of atmospheric carbon dioxide.

Bazzaz emphasizes the importance of inter- and intraspecific variation. A "big leaf" model that overlooks such differences and treats all plants as functionally identical is unlikely to be very useful in studying the effects of global change, because it cannot predict shifts in community composition and function due to shifts in the competitive abilities of different species. Furthermore, a model that does not incorporate acclimation and selection will be unable to predict short- and long-term patterns of accommodation to global change. Clark provides a masterly treatment of the importance of patch dynamics and emergent properties at higher spatial scales. A key insight is that the average productivity of a landscape of patches may deviate sharply from a simple average of their productivities, depending on the birth and death schedules of different kinds of patches. Essays by Chapin and Dawson make the simple but important point that global models might achieve realism without undue complexity by stratifying areas into broad vegetation types dominated by species with particular combinations of stature, coverage, and leaf seasonality. Finally, Ustin, Schimel, Yakir, and their associates review recent technological developments that may prove useful in integrating physiological data at regional or global scales.

Ehleringer and Field deserve praise for having assembled a pioneering volume on a topic of wide interest. But how successful is this first attempt at synthesis? If measured in terms of the interest and further research it is likely to stimulate and the accuracy with which it summarizes our current knowledge, then surely it is a success. The scaling of species interactions and ecosystem function to regional and global scales will clearly be one of the most important areas of ecological research for the next 20 years. It has great importance for our understanding of—and political decisions regarding—expected trends in global climate, productivity, and biological diversity.

Measured in terms of our ability to use the phenomena and principles it outlines to understand the behavior of the atmosphere-biosphere system, the success of the work is more limited. The book's strength—its thematic focus on photosynthesis and transpiration—is at the same time its greatest weakness. The atmosphere-biosphere system is incredibly complex, with important interactions among many scores of major compartments operating at a great variety of different spatial and temporal scales. In reading this book, I was struck by how many important ecological phenomena that ought to be included in a global synthesis were omitted or given little weight. Six seem important enough to deserve mention.

First, shifts in the competitive ability of dominant species due to climate change are likely to change the global distribution of vegetation types, and thus the pattern of energy and mass exchange over the Earth's surface. An understanding of this geographic sorting is absent from most current models, but this is an area in which ecophysiologists might make an important (and perhaps unique) contribution. What combinations of soils and climate, for example, favor evergreen as opposed to deciduous trees? What determines community trends in leaf area index and plant stature along rainfall and temperature gradients? How will enhanced CO_2 levels affect the number of overlapping leaf layers in forests?

Second, the rates of plant dispersal, succession, and soil evolution are primary constraints on the rate of biospheric response to climatic change. Paleobotanical research such as that by M. B. Davis (see her contribution to *Community Ecology*, T. J. Case and J. Diamond, Eds., Princeton University Press, 1986) can provide important insights into these rates, as can traditional ecological and pedological studies.

Third, any impact that terrestrial photosynthesis and respiration have on global CO_2 levels must be weighed against the effect of disturbances that release all or part of the carbon stored in plants and soil (for example, fire, insect outbreaks, collapse of beaver dams). Because such disturbances are ubiquitous, the net carbon budget of a landscape may bear little relationship to the low instantaneous rates of photosynthesis and instead depend heavily on the average long-term, large-scale rates of rare but heavy releases of carbon through catastrophic disturbance. Given that fires can consume a century of production in a few hours, it may be more important to study the frequency and consequences of such disturbances (and the amount of carbon stored in soils) than to worry the details of canopy photosynthesis.

Fourth, a much wider range of scale-dependent ecological phenomena than those mentioned in the text should be considered. For example, what is the feedback between plant cover and precipitation in desert regions? What is the feedback between the area covered by deciduous trees and temperature in snowy boreal latitudes? How might the area of hilly, easily eroded upland terrain in boreal regions affect the extent of minerotrophic wetlands dominated by deciduous larches? How does the extent of contiguous flammable habitat (or "fireshed") affect the local frequency of wildfire? (See T. J. Givnish, *Evolution* **35**, 101 [1981].) How does the extent of dusty regions in the Sahara lead to the fertilization of Amazonian forests?

Fifth, even though their biomass is relatively low, the pivotal role that certain animals can play in determining ecosystem function must be considered. Ungulates and termites mightily shape the structure and productivity of tropical savannas, and beavers set the tempo of disturbance and succession in many boreal wetlands. Multi-level effects that cascade through trophic webs may have equally important consequences. For example, baleen whales may play a critical role in regulating the productivity of the Antarctic Ocean by heavily grazing krill, which in turn consume planktonic algae, the primary producers. Similarly, marine fisheries that have crashed stocks of large food fish may be enhancing algal production and slowing the increase in global CO_2 levels by raising the population levels of small fish that eat zooplankton. These possibilities deserve exploration.

Finally, it is essential to incorporate the effects of the most important agent driving global change—human population growth and economic activity—directly in any analysis of the atmosphere-biosphere system. What are the effects on carbon exchange, transpiration, albedo, and rainfall of converting vast areas of rainforest to slash-and-burn fields? How do prairies and cornfields differ in their local and large-scale impacts on the biosphere? How do human activities affect the landscape pattern of natural and agricultural communities? (See D. J. Stanley and A. G. Warne, *Science* **260**, 628 [1993].) What are the synergisms among the atmospheric changes wrought by human activities (for example, between increases in ozone and carbon dioxide concentrations)? And what are the implications for ecosystem function and biospheric processes of the mass extinctions of plant and animal species projected for the coming decades? The most important determinant of ecological scaling laws—perhaps now, and certainly in the future—may be as much the human birthrate as the photosynthetic rate.

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The Binary Zoo

The Realm of Interacting Binary Stars. J. SAHADE, G. E. McCLUSKEY, JR., and Y. KONDO, Eds. Kluwer, Norwell, MA, 1993. vi, 451 pp., illus. $140, £77, or Dfl. 225. Astrophysics and Space Science Library.

One of the great scientific accomplishments of this century has been the development of a reasonably comprehensive theory of the evolution of single stars. Since the late 18th century, however, we have known that some stars are in gravitationally bound systems of two or more stars. More recent observations have revealed that in fact most stars are members of such binary or multiple systems. These range from systems in which the stars are in actual contact to those in which the stars are about a million stellar radii apart.

From the 1940s to the 1960s, as the theory of single stars was becoming firmly established, compelling ground-based evidence accumulated indicating that many close binaries of diverse types are "interacting," primarily through transfer of mass or radiant energy. The interactions can be strong enough that they profoundly affect the evolution of the component stars. The advent of space astronomy, especially in the x-ray and ultraviolet, while elucidating some previously known systems, also revealed the existence of x-ray binaries, in which various end-state objects of stellar evolution, such as compact degenerate stars or even black holes, produce copious x-rays by accreting matter from a close companion star. We are now presented with, as the editors of this volume put it, a veritable "zoo" of interacting binaries.

Although the individual contributions to *The Realm of Interacting Binary Stars* vary in their accessibility to the nonexpert, most of the authors have made an effort to develop their topics from first principles. I think the paper by Trimble and the one by Meyer-Hofmeister and Ritter are particularly effective in this regard. I found myself wishing for a chapter of similar clarity that would bring all the disparate systems together in a coherent evolutionary picture. Unfortunately, such a picture simply does not exist at present.

I am impressed, as an informed outsider, both by the advances in knowledge that have been made and by the mysteries that remain. On the one hand, we know much more than we once did about cataclysmic variables, nova outbursts, type I supernovas, massive x-ray binaries, and stellar activity. On the other hand, we still do not understand the nature, origin, or fate of classically known systems like the relatively common W Ursae Majoris contact systems or of oddballs like ϵ Aurigae. Among more recently discovered systems, we have considerable difficulty with the whole class of low-mass x-ray binaries and millisecond pulsars, and we do not even know the nature of the mass accreting object in exotic systems like SS433. Encouraging progress is being made in the areas of mass flow in Algols and the origins of binary stars, and new, more effective observation techniques are being developed.

Certainly there remains much work to be done, by observers and theorists alike, to achieve the same fundamental clarity about binary star evolution that we now possess for single stars. I think this book will be useful to those who strive to develop that understanding.

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NMR for Beginners

Fundamentals of Nuclear Magnetic Resonance. JACEK W. HENNEL and JACEK KLINOWSKI. Longman Scientific and Technical, Harlow, Essex, U.K., and Wiley, New York, 1993. xii, 288 pp., illus. $49.95 or £22.50.

Since its discovery in 1945 by Purcell, Torrey, and Pound at Harvard University and by Bloch, Hansen, and Packard at Stanford University, nuclear magnetic resonance (NMR) has become a powerful research tool in many different fields that touch our everyday lives. It has been used in the determination of the chemical structure of complex molecules of biological significance, the study of the basic properties of technologically important new materials such as high-T_c (high transition-temperature) superconducting ceramics, and mineral exploration. Magnetic resonance imaging is now an important instrument in medical diagnostics. These widespread applications have made a basic understanding of NMR essential for students in many scientific disciplines outside of physics. There has long been a need for an