

# SPECIAL FEATURE

## Terrestrial and Freshwater Biogeochemistry<sup>1</sup>

Science, like fashion, runs in cycles. Biogeochemistry, the study of elemental cycles affected by life, is arguably a century old, as indicated by Svante Arrhenius's early exploration on carbon dioxide and climate, and certainly half a century old, as illustrated by Vladimir Vernadsky's and Alfred Redfield's studies of global biogeochemical cycles. Despite its age, biogeochemistry is back in vogue for good reason. Today's environmental problems are global and complex, and they cannot be addressed successfully within traditional disciplinary boundaries of biology or geology or chemistry. Biogeochemistry will help provide the scientific foundation to solve them. The solutions will depend on understanding and judiciously managing the cycles of elements on Earth.

This Special Feature marks the formation of a new Biogeosciences section within the Ecological Society of America (ESA). Biogeochemists have long been active within ESA. The new section provides an opportunity to increase the visibility and quality of biogeochemistry research in terrestrial, freshwater, and marine systems. The focus of this particular Special Feature is narrower: terrestrial and freshwater biogeochemistry and some links between them.

The feature begins with papers by G. E. Likens and by N. van Breemen and R. F. Wright that address the historical context for biogeochemistry research today. Likens describes the 40-year history of biogeochemical research at the Hubbard Brook Experimental Forest. Based on the small watershed-ecosystem approach, this research has been instrumental in identifying acid rain in the United States and in demonstrating the close links between land-use change and the downstream chemistry of the watersheds. Van Breemen and Wright examine the history of watershed-scale (or, following European usage, "catchment-scale") biogeochemistry in Europe. That history begins in the early 20th century with the Swiss botanist Arnold Engler, the first person to monitor runoff from catchments and consider its relationship with land use. It continues through the important discoveries of acid rain and nitrogen saturation in Europe. Both Likens and van Breemen and Wright discuss the extended time scales needed for ecosystems to recover that must be considered in managing ecosystem recovery from acid rain and similar large-scale perturbations. They also provide recommendations and opportunities for future biogeochemical research.

The next three papers provide examples of current biogeochemical research at scales from single streams to the globe. S. G. Fisher, R. A. Sponseller, and J. B. Heffernan examine the convergence of stream ecology and the ecosystem concept through biogeochemistry. They discuss nutrient spiraling as a conceptual tool to resolve the dynamics of organic and inorganic materials in streams of diverse sizes and flow rates. They emphasize the importance of studying spatially explicit flowpaths that connect streams to ecosystem types and landscapes. E. G. Jobbágy and R. B. Jackson examine how plant stoichiometry and nutrient uptake alter the distribution of soil nutrients locally and globally. Primary succession can change the relative abundance of soil nutrients to depths of several meters. Micronutrients show some of the most pronounced changes, with plant stoichiometry playing an important role in generating the patterns observed. In the absence of such nutrient uplift by plants, the authors examine the extent to which global nutrient pools would be smaller than observed. The theme of ecological stoichiometry also plays an important role in the contribution by M. E. McGroddy, T. Daufresne, and L. O. Hedin. They examine global variations of C:N:P stoichiometry of forest systems worldwide, focusing on ratios in foliage and litter. Their data are discussed in the context of bottom-up forces from physiological constraints and top-down pressures imposed by nutrient cycles. When coupled in time and space, these forces offer the essential dynamics necessary for the emergence of selective and evolutionary

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feedbacks on strategies of nutrient use at the level of individual plants, and on macroscopic patterns in C, N, and P cycling at the level of ecosystems and biomes.

After the Special Feature's look to the past and present, W. H. Schlesinger looks to the future to recommend priorities for biogeochemical research, including studies in ecological stoichiometry and microbial dynamics. His recommendations include the need for large-scale, long-term field experiments that examine multiple interacting factors. Finally, he challenges the science community to unlock the secrets of the Earth's chemical system and the role of life in it—hence *biogeochemistry*.

Given today's complex environmental problems and the demands of global change research, we predict that biogeochemistry, and biogeosciences in general, will be fashionable for a long time to come.

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