Conclusion

An analogy is commonly made between the earth’s surface system and a giant chemical engineering factory. In the natural system, material circulation is driven by energy from the sun and, to a much lesser extent, from radioactive decay of elements in the earth’s interior and motions of its tides. This is a mechanical and inorganic view of the earth. In another and more realistic sense, the earth has a natural metabolism; materials have circulated about its surface for millions of years in a complex, interconnected web of biogeochemical cycles. An array of physical, chemical, and biological processes weather and erode rocks and transfer materials in and out of the atmosphere, from the atmosphere to the biota and back again, to the oceans via rivers, and to the continents by uplift. Each element has a natural biogeochemical cycle. It is these cycles and their relationship to the physical climate system that have led to the development of a relatively stable and resilient surface system during geologic time. Life has evolved in this system and plays a strong role in the development and maintenance of the system through processes, fluxes, and feedbacks.

Human activities have contributed materials to the biogeochemical cycles. Some of these materials enter element cycles already naturally in operation; they are the same chemical species that have circulated for millions of years. Other materials are synthetic compounds and are foreign to the natural environment. These anthropogenic fluxes are leading to a number and variety of environmental issues, including the possibility of global climate change. There is no doubt that human activities have interfered in biogeochemical cycles and have modified the composition of the atmosphere. Understanding the consequences of this interference requires better quantitative descriptions of these cycles, their interconnections, and, in particular, their coupled response to perturbations, such as a change in climate.