Fungi in Biogeochemical Cycles

Fungi have important roles in the cycling of elements in the biosphere but are frequently neglected within microbiological and geochemical research spheres. Symbiotic mycorrhizal fungi are responsible for major transformations and redistribution of inorganic nutrients, while free-living fungi have major roles in the decomposition of organic materials, including xenobiotics. Fungi are also major biodeterioration agents of stone, wood, plaster, cement and other building materials, and are important components of rock-inhabiting microbial communities. The aim of this book is to promote further understanding of the key roles that free-living and symbiotic fungi (in mycorrhizas and lichens) play in the biogeochemical cycling of elements, the chemical and biological mechanisms that are involved, and their environmental and biotechnological significance. Where appropriate, relationships with bacteria are also discussed to highlight the dynamic interactions that can exist between these major microbial groups and their integrated function in several kinds of habitat.

The British Mycological Society promotes all aspects of fungal science. It is an international society with members throughout the world. Further details regarding membership, activities, and publications can be obtained at *www.britmycolsoc.org.uk*.

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In loving memory of my mother, Mary (Sheila) Gadd, who encouraged my love of the natural world from an early age

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Preface

In praise of geomycology

Interactions between the microbially dominated biosphere and the geosphere have and are profoundly affecting our planet and all life on it. Geomicrobiology can be defined as the study of the role that microbes have played and are playing in processes of fundamental importance to geology, and within the diffuse boundaries enclosed by this definition, fungi are important components. Some of the major geological processes affected by microbial activities include mineral formation, mineral degradation (including weathering, bioleaching, soil and sediment formation), element cycling and fossil fuel genesis and degradation. The cycling of component elements from organic and inorganic substrates as a result of these processes can be termed biogeochemical cycling, which again emphasizes the interplay between physicochemical and biological mechanisms. The study of the roles and importance of fungi as agents of geological change can be termed *geomycology* and fungi are ideally suited for this purpose. The branching, filamentous mode of growth allows efficient colonization and exploration of solid substrates while extracellular release of enzymes and other metabolites mediates many organic and inorganic transformations. Considerable physical force can arise from hyphal penetration while translocation of resources through the mycelium enables exploitation of environments where nutrients have an irregular distribution. Fungi can attack silicates, carbonates, phosphates and other minerals while their carbonaceous predilections are well-known, extending to recalcitrant organic molecules of natural origin, e.g. lignin and chitin, or from anthropogenic activity, e.g. pesticides and other xenobiotics.

While considerable attention has been directed towards bacteria in geomicrobiology because of their incredible environmental and metabolic

diversity, which includes major transformations in anaerobic environments such as the deep subsurface, fungi have received less attention or are rather taken for granted, biogeochemical activities being submerged in more general perspectives. For example, fungi are more commonly associated with organic matter decomposition and therefore carbon (and nitrogen) cycling, although it should be appreciated that every stable element can be associated with living organisms: any decomposition process involves cycling of all constituent elements present in dead organic matter including those accumulated from the environment. Fungi are often associated with phosphate mobilization from inorganic sources yet little attention is given to the fate of associated metals and other components in minerals. Symbiotic fungi such as mycorrhizas, associated with the vast majority of plant species, have an enormous influence on plant growth and nutrient cycling while lichens are primary rock colonizers and therefore involved in the very earliest stages of rock and mineral transformation, and soil development. As well as being of major importance in the plant root-soil aerobic zone, our knowledge of the boundaries of the biosphere are being extended continually and fungi are now known to be components of such habitats as the deep subsurface and aquatic sediments, and 'extreme' locations such as those of high salinity or containing high levels of toxicants. Biogeochemical activities of fungi are also relevant to the natural attenuation of polluted habitats and the bioremediation of organic and inorganic pollution, but, on the negative side, are also involved in the biodeterioration of stone, wood, plaster, cement and other building materials.

The prime objective of this book is to highlight the roles and importance of fungi in biogeochemical cycles and give an account of the latest understanding of the physical, chemical and biological mechanisms involved and their significance in the biosphere and for other organisms. Where appropriate, relationships with bacteria are also discussed to highlight the dynamic interactions that can exist between these major microbial groups and their integrated function in several kinds of habitat. The chapters are written by leading international authorities and represent a unique synthesis of this subject area, hopefully with broad appeal not only to mycologists and microbiologists but to environmental scientists, geologists, earth scientists, ecologists and environmental biotechnologists.

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