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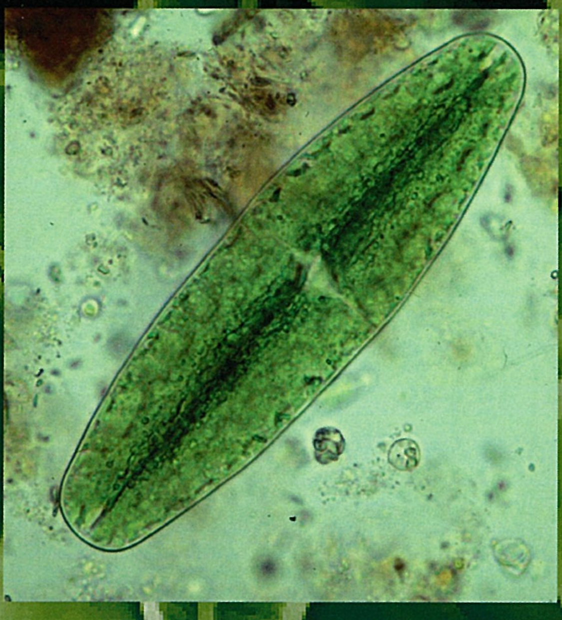
Dilwyn J. Griffiths

Microalgae and Man



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Preface

The microalgae, with representatives in all but one of the major algal divisions, are an important component of the biota of the world's aquatic environments. They include the phytoplankton that are responsible for a large proportion of the primary production of all marine and freshwater bodies. They occur at the base of the food chains upon which the world's fisheries industries depend, and are a vital component in the numerous aquaculture projects upon which the world will increasingly come to rely for a large portion of its protein requirement. Their use for the mass production of stock feed and for direct human consumption, already being practised in many parts of the world, is likely to become of increasing importance in the future as is the exploitation of their ability to serve as a source of key metabolites in the food industry and in the synthesis of a range of other high-value products. The mass culture of microalgae under controlled conditions is also under consideration for its potential to provide an alternative source of biomass and for the production of biofuels, such as biodiesel, that does not compete for land that can be more profitably used for the production of traditional food crops. The potential of microalgae as a commercial source of another energy source, hydrogen, is also under investigation with a view to exploiting the ability of some microalgae, unique among oxygenic photosynthetic organisms, to release hydrogen gas produced from the photolytic splitting of water. The proven role of microalgae in wastewater treatment and in various environmental remediation processes as well as their potential contribution as a key component of a range of carbon-capture schemes is also likely to become of increasing importance in the future.

This book surveys our current understanding of those aspects of the biology of microalgae which constitute the basis of the range of practical applications now under consideration for their potential contribution to human health and well-being. The focus is largely on physiological and biochemical processes of microalgae as they are currently known, with the aim of providing some of the basic background information against which present and proposed future developments can be viewed. Many of the latter developments, if they are to be successful, will require collaboration of engineers, process biochemists and microbiologists as well as those capable of assessing economic and environmental considerations. It is hoped that this book, will provide for such workers, for students and for the lay-person, an overview of some of the relevant basic biology of the microalgae, highlighting their metabolic flexibility and their vast potential as a valuable resource that is yet to be fully realised.

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Finally, I thank my wife, Elen, for her unfailing support and encouragement. This book is dedicated to her.

Introduction

The microalgae constitute an arbitrary grouping of the smaller microscopic and mostly unicellular photosynthetic organisms, many of which have much in common with some other non-photosynthesising unicellular organisms, such as the slime moulds, various ciliates and other "protozoa". According to some classification schemes they are placed with these other groups in the kingdom Protista (Corliss, 1984) thus separating the microalgae from the other larger (multicellular) algae. The microalgae are, in fact, represented in all but one of the commonly recognised phyla (divisions) of algae, namely, the chlorophyta (green algae), chrysophyta, cryptophyta, dinophyta (dinoflagellates), euglenophyta (euglenoids), glaucophyta, haptophyta (includes the coccolithophorids which in some schemes are placed with the chrysophyta), ochrophyta (diatoms or bacillariophyta) and rhodophyta (red algae). Another group traditionally included with the microalgae is the cyanobacteria although, like the photosynthetic bacteria, they are prokaryotic and taxonomically belong in a different kingdom, the Monera. Including the cyanobacteria with the true microalgae recognises some basic similarities of ecology and physiology, in particular their common possession of an oxygenic photosynthetic mechanism. The microalgae are also generally taken to include colonial forms in which otherwise independent individuals, when they divide, produce daughter cells that tend to remain together in a loose association often for a number of further divisions to yield coenobia. Some of the simpler filamentous forms are also included with the microalgae.

The microalgae, therefore, constitute a polyphyletic group of some 25,000 morphologically defined species. They are often the most dominant organisms in aquatic ecosystems, both marine and freshwater, where, as phytoplankton, they occupy an important position as primary producers at the base of the food chains. They have long been recognised for their contributions to a range of human activities and for their impact upon various aspects of human health and wellbeing. The role of microalgae in sustaining natural fisheries world wide has, in recent decades been considerably expanded through their use in aquaculture where they often provide a more economic, and for certain cultured fish, crustacean and shell-fish species at certain critical stages of their development, an indispensable food source. The relative ease with which certain of the microalgae can be grown in culture under controlled conditions has led to their being extensively used for biomass production, so far largely at the pilot-plant level but increasingly on a large scale in ponds, raceways and various forms of photobioreactor systems. They are increasingly being used to supplement the more traditional forms of stock feed and even as a source of essential components of human diets.

Current concerns over the environmental impacts and the likely increasing costs of our ever-growing demands for fossil fuels to meet our energy requirements has focussed attention on microalgae as possible sources of replacement fuels. Compared with other biofuel sources currently in use, such as corn, soybean or sugar cane, microalgae have the advantage of being amenable to culture on non-arable land and in fresh and salt- water environments. Moreover, they are capable of rapid growth and the entire cellular mass can, under suitable conditions and with appropriate technology, be harvested virtually continuously. The ability of many microalgal species to supplement photosynthetic production by using a range of organic substrates as alternative sources of carbon and energy offers the possibility of linking their biomass production with effluent and waste-water treatment so offsetting some of the costs of the necessary plant and equipment. The ability of microalgae to grow in media enriched with CO_2 (up to 10%) offers the possibility of enhanced biomass production while, at the same time, providing a possible mechanism for CO_2 capture from flue-gas emissions from a range of industrial sources. Hydrogen production, well known for many years as a unique feature of microalgal photosynthesis, is now receiving considerable attention in the search for alternative sources of energy. The practicality of harnessing this feature of microalgal biochemistry on a large scale, as is the case with many other proposed applications, requires careful consideration and costing. It is hoped that this book, through its survey of the contribution of microalgae to human health and well-being, and through its coverage of the relevant aspects of microalgal biology underpinning these practical applications, will provide a background against which current and future developments in this exciting field of biology/biotechnology can be appreciated.