Advances in Experimental Medicine and Biology

Volume 979

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Euglena: Biochemistry, Cell and Molecular Biology

Springer

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ISSN 0065-2598 ISSN 2214-8019 (electronic)
Advances in Experimental Medicine and Biology
ISBN 978-3-319-54908-8 ISBN 978-3-319-54910-1 (eBook)
DOI 10.1007/978-3-319-54910-1

Library of Congress Control Number: 2017936664

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This volume is dedicated to the trailblazers, the late Shozaburo Kitaoka and the late Jerome A. Schiff, who recognized the potential of Euglena and over the years provided training, encouragement, and guidance as we endeavored to shed light on its fascinating and novel biology.

Preface

For over 50 years, *Euglena* has been an organism of choice for addressing fundamental questions in eukaryotic biochemistry and cellular and molecular biology. *Euglena* grows rapidly in the dark to high cell densities using a diverse array of organic compounds and industrial waste streams. Rapid growth is also achieved in the light using photosynthesis as the sole source of carbon and energy for growth or using both photosynthesis and organic carbon. Grown in the dark, *Euglena* has a poorly developed plastid which upon light exposure develops into a photosynthetically competent chloroplast. Unique among photosynthetic organisms, the chloroplast is totally gratuitous to growth. Permanently white relatives of photosynthetic euglenoids are found in nature, and chloroplast loss is readily induced by a variety of treatments in the laboratory. Due to a rapid growth rate combined with simple nutritional requirements, the large number of cells required for isolation of subcellular organelles can easily be obtained in less than a week allowing both in vivo and in vitro studies of organelle biochemistry and molecular biology.

The availability of large quantities of permanently white and green *Euglena* resulted in the *Euglena* chloroplast being among the first photosynthetic organelles whose genome was physically characterized and sequenced. The undeveloped plastids in dark-grown *Euglena*, the facile induction by light exposure of the enzymatic machinery required to transform the plastid into a photosynthetically competent chloroplast, and the subcellular organelle which allows CO_2 to be used as the sole source of carbon and energy for growth made *Euglena* a model system for studies of organelle biogenesis. Studies of *Euglena* were instrumental in establishing the contribution of the nuclear and chloroplast genome to the development of chloroplasts. As additional information became available from studies of higher plants and other algae, it became apparent that *Euglena* was an atypical organism; it had its own way of doing things. The focus of *Euglena* research shifted from being a model organism to being an organism that could be used to elucidate novel patterns of genome organization, transcript processing, gene expression, and transport of proteins to chloroplasts providing insights into the evolutionary origin of eukaryotic cellular processes.

The diverse nature of organic carbon compounds and industrial waste streams supporting growth, the ability to grow photosynthetically, and the evolutionary relationship to the parasitic trypanosomes make *Euglena* an organism of choice for investigations of diverse and in some cases unique

biochemical pathways. *Euglena* mitochondria are the site of a classical respiratory pathway, an alternative respiratory pathway, and an anaerobic fermentation pathway producing wax esters. The photorespiratory pathway and glyoxylate pathway for ethanol assimilation are localized in most organisms to specialized organelles called microbodies, but these metabolic pathways appear to be localized to *Euglena* mitochondria. During photosynthetic and aerobic growth, *Euglena* produces a β-1,3-glucan, paramylum, as the major storage product, while wax esters are accumulated during mitochondrial anaerobic fermentation. A number of uses for paramylum have been found, and the *Euglena* wax ester has potential as a biofuel. *Euglena* accumulates nutraceuticals and cosmeceuticals, and its biomass has a large nutritional value. The novel nature of the biochemical pathways found in *Euglena* makes it a source of genes for genetic engineering of other organisms for production of high-value compounds.

The facile large-scale cultivation of *Euglena* on a wide array of organic compounds and industrial waste streams over a pH range of approximately 3.5–9 taken together with its metabolic diversity suggests a multitude of potential biotechnology applications. To make this potential a reality requires an in-depth understanding of the biochemistry and cellular and molecular biology of *Euglena*. Our current knowledge regarding these topics is plentiful, but it is scattered throughout the plant, protist, biochemical cell biology, and evolutionary biology literature of the past 50 years. It is over 25 years since the final volume of the four-volume compilation of *Euglena* biochemical and molecular biology research, *The Biology of Euglena*, appeared. The 14 chapters of this volume are contributed by well-known experts who in many cases played a major role in elucidating the phenomena discussed. The content is divided into three sections. The first section describes novel biochemical pathways which in some cases have an atypical subcellular localization. The next section details atypical cellular mechanisms of organelle protein import, organelle nuclear genome interdependence, and gene regulation and expression providing insights into the evolutionary origins of eukaryotic cells. The final section discusses how biotechnologists have capitalized on the novel cellular and biochemical features of *Euglena* to produce value-added products. The reader will come away from this volume with an understanding of the atypical biochemistry and cellular and molecular biology of one organism, *Euglena*, and realize the diversity of cellular processes yet to be discovered on the different branches of the tree of life.

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