

The evolution of life cycles with haploid and diploid phases

Barbara K. Mable and Sarah P. Otto*

Summary

Sexual eukaryotic organisms are characterized by an alternation between haploid and diploid phases. In vascular plants and animals, somatic growth and development occur primarily in the diploid phase, with the haploid phase reduced to the gametic cells. In many other eukaryotes, however, growth and development occur in both phases, with substantial variability among organisms in the length of each phase of the life cycle. A number of theoretical models and experimental studies have shed light on factors that may influence life cycle evolution, yet we remain far from a complete understanding of the diversity of life cycles observed in nature. In this paper we review the current state of knowledge in this field, and touch upon the many questions that remain unanswered. *BioEssays* 20:453–462, 1998. © 1998 John Wiley & Sons, Inc.

Introduction

In 1851, Hofmeister¹ recognized that plants alternate between two distinct phases, yet it was not until 1894 that Strasburger² proposed that this “alternation of generations” represented an alternation between haploid and diploid phases.³ Such an alternation of generations is a necessary consequence of sexual reproduction, since a haploid phase must follow meiosis and a diploid phase must follow gamete fusion, but the lengths of these two phases vary widely among organisms.⁴ This variability is especially pronounced among such organisms as algae and protists, which have life cycles ranging from complete haploid development to complete diploid development, as illustrated in Figure 1.

During the past 20 years, there has been a resurgence of interest in the evolution of life cycles and ploidy levels. However, much of both the theoretical^{5–12} and experimental^{13–18} work has concentrated on how and why diploidy has evolved as the dominant state in “higher” plants and animals (reviewed in ref. 19). This focus on the advantages of diploidy has tended to hinder our understanding of the diversity of life cycles seen among organisms and in some cases has

resulted in erroneous interpretations of comparative patterns (as argued in ref. 20). Recently, the focus has shifted toward a somewhat more interesting question: why do many eukaryotes (e.g., many protozoa, algae, fungi, mosses, and ferns) maintain an alternation of generations in which there is substantial development in both haploid and diploid phases? This shift has led to a number of theoretical predictions about when we might expect to see the evolution of haplonty (somatic development only in the haploid phase), diplonty (somatic development only in the diploid phase), or haploid-diploidy (somatic development in both phases). The purpose of this review is to outline the type of variation in life cycles that exists among eukaryotes, summarize theoretical and experimental studies of life cycle evolution, and suggest directions for future research.

Life cycle variation among eukaryotes

The fact that nearly all metazoan taxa undergo somatic development as diploids has strongly shaped our perception of life cycles, leading to a belief in the inherent superiority of the diploid state. One notable exception to complete diplonty is the occurrence of ammenotokous animal species, in which haploid males are produced parthenogenetically by diploid females, which are themselves produced sexually (Table 1). Among zoologists, the term “haplo-diploid” is usually reserved to describe taxa with haploid males and diploid females, and so we will use “haploid-diploid” to refer to organisms that alternate between independent haploid and

Department of Zoology, University of British Columbia, Vancouver, BC, Canada.

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*Correspondence to: Sarah P. Otto, Department of Zoology, University of British Columbia, Vancouver, BC V6T 1Z4, Canada; E-mail: mable@zoology.ubc.ca, otto@zoology.ubc.ca

Evolution Of Haploid Diploid Life Cycles

Karl J. Niklas



Evolution Of Haploid Diploid Life Cycles:

The Evolution of Haploid-diploid Life Cycles Mark Kirkpatrick, 1994 The haploid diploid alternation of generation is among the most fundamental features of eukaryotic life Until recently however little research had been done on the origin and evolution of this genetic system Bringing together for the first time emerging empirical and theoretical perspectives on this topic this volume contains the proceedings of the 1993 Symposium on Some Mathematical Questions in Biology The Evolution of Haploid Diploid Life Cycles held in June 1993 in Snowbird Utah The volume opens with a broad survey of life forms which reveals a wide diversity of life cycles including predominantly haploid cycles predominantly diploid cycles and mixed cycles Mathematical models attempt to explain this diversity in terms of evolutionary forces that include deleterious mutation advantageous mutation and ecological selection A review of the first experimental studies shows how the hypotheses suggested by the models may ultimately be resolved The book introduces biologists to mathematical approaches to these problems and introduces mathematical biologists to comparative and experimental approaches Opportunities for future research are highlighted throughout *Understanding Biology Through Evolution - Fourth Edition* Bruce D. Olsen, 2009-09-01 This is the fourth edition of a clear effective study guide written by Mr Olsen to help students in an introductory level college biology course master the fundamentals and get the best possible grade Written especially for non majors the concise explanations of core biology concepts are accompanied throughout with helpful illustrations and tables The author s objective is to illustrate how the concept of evolution is the key to understanding the major sub disciplines of biology including genetics ecology biodiversity botany and zoology **The Evolutionary Biology of Plants** Karl J. Niklas, 1997-06-08 Provides a comprehensive synthesis of modern evolutionary biology as it relates to plants This text recounts the saga of plant life from its origins to the radiation of the flowering plants Through computer generated walks it shows how living plants might have evolved **Marine Macro- and Microalgae** F. Xavier Malcata, Isabel Sousa Pinto, A. Catarina Guedes, 2018-12-07 The marine environment accounts for most of the biodiversity on our planet while offering a huge potential for the benefit and wellbeing of mankind Its extensive resources already constitute the basis of many economic activities but many more are expected in coming years This book covers current knowledge on uses of marine algae to obtain bulk and fine chemicals coupled with optimization of the underlying production and purification processes Major gaps and potential opportunities in this field are discussed in a critical manner The current trends pertaining to marine macro and microalgae are explained in a simple and understandable writing style This book covers a wide variety of topics and as such it will be appropriate as both student text and reference for advances researchers in the field **The Algae World** Dinabandhu Sahoo, Joseph Seckbach, 2015-12-16 Algal World has been carefully written and edited with an interdisciplinary appeal and aims to bring all aspects of Algae together in one volume The 22 chapters are divided into two different parts which have been authored by eminent researchers from across the world The first part Biology of Algae

contains 10 chapters dealing with the general characteristics classification and description of different groups such as Blue Green Algae Green Algae Brown Algae Red Algae Diatoms Xanthophyceae Dinophyceae etc In it has two important chapters covering Algae in Extreme Environments and Life Histories and Growth Forms in Green Algae The second part Applied Phycology contains 12 chapters dealing with the more applied aspects ranging from Algal Biotechnology Biofuel Phycoremediation Bioactive Compounds Biofertilizer Fatty Acids Harmful Algal Blooms Industrial Applications of Seaweeds Nanotechnology Phylogenomics and Algal culture Techniques etc

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Theoretical investigations of the evolution of haploid-diploid life cycles Cheryl Diane Jenkins, 1994

Evolution After Darwin: The evolution of life Sol Tax, 1960 Papers presented at the University of Chicago Darwin centennial celebration in November 1959 Vol 3 includes index for the set and a record of the celebration

Plant Breeding Reviews, Volume 38 Jules Janick, 2014-11-17 Plant Breeding Reviews presents state of the art reviews on plant genetics and the breeding of all types of crops by both traditional means and molecular methods Many of the crops widely grown today stem from a very narrow genetic base understanding and preserving crop genetic resources is vital to the security of food systems worldwide The emphasis of the series is on methodology a fundamental understanding of crop genetics and applications to major crops It is a serial title that appears in the form of one or two volumes per year

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Fourteenth International Seaweed Symposium A.R.O. Chapman, Murray T. Brown, Marc Lahaye, 2012-12-06 Industrial seaweed use started in Brittany in the XVII century Today 700 species have been identified along 1000 km of shoreline producing 10 million tons of biomass In the Fourteenth International Seaweed Symposium the latest developments in the area are discussed The blending of molecular biology with traditional taxonomy is improving our understanding of phylogeny and species relationships among many of the important algae A new generation of biologically based management models is gradually incorporating field testing concepts from ecological theory and principles from population biology Prediction is being improved and an appropriate balance is being struck between commercial exploitation and the preservation of wild seaweed resources Cell and tissue culture of seaweeds is entering the mass production phase Field farming is now entering the large scale production area New biologically active compounds are being described obtained from algae and new tools for the characterisation of phytocolloids are described Microalgal blooms and toxins are also experiencing a flourish of new results

Seaweeds and their Role in Globally Changing Environments Alvaro Israel, Rachel Einav, Joseph Seckbach, 2010-06-18 Global warming is accelerating faster than the ability for natural repair and environmental stresses are damaging ecosystems all affecting physical and biological systems on Earth A new Nasa led study shows that human activity has caused climate changes resulting in permafrost thawing acid rain and lower productivity in lakes as well as increased emissions of greenhouse gases including CO₂ N₂O CH₄ CF₃ and CFC Marine plants play a vital role in maintaining the balance of marine environments while serving as a source of food for humankind and important chemical compounds Microalgae and seaweed have enormous potential for reducing global warming and climate change During photosynthesis algae grow draw CO₂ from the atmosphere release oxygen and produce solar biofuel Experts in the life of marine plant ecosystems in globally changing environments contributed chapters to this book The target readers are phycologists ecologists atmospheric scholars conservationists environmentalists and ecologically aware laymen

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Dissertation Abstracts International, 1995 *Robustness and Evolvability in Living Systems* Andreas Wagner, 2013-10-24 All living things are remarkably complex yet their DNA is unstable undergoing countless random mutations over generations Despite this instability most animals do not grow two heads or die plants continue to thrive and bacteria continue to divide *Robustness and Evolvability in Living Systems* tackles this perplexing paradox The book explores why genetic changes do not cause organisms to fail catastrophically and how evolution shapes organisms robustness Andreas Wagner looks at this problem from the ground up starting with the alphabet of DNA the genetic code RNA and protein molecules moving on to genetic networks and embryonic development and working his way up to whole organisms He then develops an evolutionary explanation for robustness Wagner shows how evolution by natural selection preferentially finds and favors robust solutions to the problems organisms face in surviving and reproducing Such robustness he argues also enhances the potential for future evolutionary innovation Wagner also argues that robustness has less to do with organisms

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