

REVIEW

SPECIAL ISSUE

DEVELOPMENTAL PLASTICITY: FROM MECHANISMS TO EVOLUTIONARY PROCESSES

Twenty years on from *Developmental Plasticity and Evolution*: middle-range theories and how to test them

Tobias Uller*, Lisandro Milocco, Jana Isanta-Navarro, Charlie K. Cornwallis and Nathalie Feiner

ABSTRACT

In *Developmental Plasticity and Evolution*, Mary-Jane West-Eberhard argued that the developmental mechanisms that enable organisms to respond to their environment are fundamental causes of adaptation and diversification. Twenty years after publication of this book, this once so highly controversial claim appears to have been assimilated by a wealth of studies on ‘plasticity-led’ evolution. However, we suggest that the role of development in explanations for adaptive evolution remains underappreciated in this body of work. By combining concepts of evolvability from evolutionary developmental biology and quantitative genetics, we outline a framework that is more appropriate to identify developmental causes of adaptive evolution. This framework demonstrates how experimental and comparative developmental biology and physiology can be leveraged to put the role of plasticity in evolution to the test.

KEY WORDS: Plasticity, Evolution, Evolvability, Development, Adaptive landscape, Morphospace

Introduction

Organisms are inherently responsive to their environment; they modify their morphology and physiology to fit their surroundings; switch between food sources when nutrients become depleted, or move to new locations where conditions are more favourable. Establishing whether or not such short-term environmental responsiveness, or plasticity, is related to long-term evolutionary patterns is a persistent problem in biology.

In an influential attempt to provide a solution, Mary-Jane West-Eberhard in her book *Developmental Plasticity and Evolution*, followed a long tradition of thinkers in arguing that evolutionary biologists should ‘put the flexible phenotype first, as the product of development and the object of selection’ and she encouraged biologists to ‘examine the consequences for the genetic theory of evolution’ (West-Eberhard, 2003, p. 3). Following publication of this book 20 years ago, West-Eberhard’s advocacy for the constructive role of development in adaptive evolution was both criticised and defended (e.g. de Jong and Crouser, 2003 versus Badyaev, 2005), and developmental plasticity has since become central to debates concerning the structure of evolutionary theory (e.g. Laland et al., 2014 versus Wray et al., 2014; reviewed in Laland et al., 2015). A persistent criticism has been that there is a lack of ‘middle-range theories’: theories that make specific predictions about the observable traces of developmental plasticity in evolution,

accompanied with guidance of how to collect evidence that can discriminate between competing hypotheses (Kovaka, 2019).

The aim of this paper is to demonstrate how this domain could be filled. First, we briefly reflect on the extent to which research on developmental plasticity and evolution has come to embrace West-Eberhard’s emphasis on ‘development, not selection, [as] the first-order cause of design’ (West-Eberhard, 2003, p. 141). We suggest that research on ‘plasticity-led’ evolution in fact has developed in a way that largely bypasses developmental explanations for adaptation, which makes such research more compatible with interpreting adaptive evolution solely in terms of selection on genetic variation. Second, we connect developmental plasticity to the contemporary literature on evolvability to illustrate how to assign adaptive bias in evolution to both developmental and selective processes. We demonstrate that this can help to formulate hypotheses for when, where and why plasticity will ‘take the lead’ in adaptive evolution, and identify areas that would benefit from further theoretical and empirical development. Third, we provide suggestions for how experimental and comparative biology can put those theories to the test, thereby integrating developmental and selective explanations of adaptation and diversification.

Developmental plasticity and the causes of adaptive change

Evolution is often described as a two-step process, beginning with the origin of a phenotypic variant, followed by the spread and establishment of this variant (e.g. West-Eberhard, 2003, chapter 6). In biological systems, each of these steps can impose an adaptive bias or directionality on evolution. The second step is the more familiar: competition between individuals and ‘the struggle for existence’ bias evolutionary change towards phenotypes that confer survival or reproductive benefits, making organisms appear designed to their way of life. However, as West-Eberhard argued, adaptive bias also arises from the capacity of individual organisms to accommodate genetic and environmental perturbation through the ‘adaptive mutual adjustment among variable parts during development without genetic change’ (West-Eberhard, 2003, p. 51). Such ‘phenotypic accommodation’ results in the appearance of new phenotypic variants whose match to the local environment will be assessed by their effects on survival and reproduction (note that, throughout *Developmental Plasticity and Evolution* and in the present paper, ‘development’ refers to ‘all phenotypic change during the lifetime of an individual’; West-Eberhard, 2003, p. 32).

The constructive role of development in adaptive evolution may appear at odds with the historically wide-spread belief that ‘allele frequency change caused by natural selection is the only credible process underlying the evolution of adaptive organismal traits’ (Charlesworth et al., 2017; West-Eberhard, 2003, p. 10). It is obviously true that the mechanisms of phenotypic accommodation have evolved, and thus have persisted and been modified through countless rounds of natural selection (although this does not imply

*Department of Biology, Lund University, 223 62 Lund, Sweden.

*Author for correspondence (tobias.uller@biol.lu.se)

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Developmental Plasticity And Evolution Developmental Plasticity And Evolution

Eugene Gollin



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Developmental Plasticity and Evolution Mary Jane West-Eberhard, 2003-03-13 West Eberhard widely recognized as one of the most incisive thinkers in evolutionary biology assesses all the evidence for our current understanding of the role of changes in body plan and development for the process of speciation The process of evolution is systematically reassessed to integrate the insights coming from developmental genetics Developmental Plasticity Eugene Gollin, 2012-12-02

Developmental Plasticity Behavioral and Biological Aspects of Variations in Development explores the behavioral and biological aspects of variations in development from a variety of theoretical viewpoints and research contexts Topics covered include evolution and genetic variability sensory bases of infant perception and learning and ethology The infancy of human learning processes is also discussed along with epistemology and developmental psychology Comprised of eight chapters this book opens with a review of the broad evolutionary landscape and the specific genetic mechanisms implicated in biological and behavioral development It then describes the sensory apparatus available to neonatal human beings and analyzes the similarities and differences between ethological theory and learning theory Developmental plasticity is also examined in interdisciplinary contexts while the acquisition of behavior patterns during early postnatal development is explored from a traditional learning theory point of view The remaining chapters focus on the role played by asymmetry in general and by cerebral asymmetry in particular in the generation of individuality cultural and biological instances of plasticity in development and the barriers separating epistemology from developmental psychology and psycholinguistics This monograph will be a useful resource for developmental psychologists and other professionals devoted to child development and learning as well as those in the fields of genetics and behavioral and biological sciences **Evolution** Wallace

Arthur, 2011-01-25 This book is aimed at students taking courses on evolution in universities and colleges Its approach and its structure are very different from previously published evolution texts The core theme in this book is how evolution works by changing the course of embryonic and post embryonic development In other words it is an evolution text that has been very much influenced by the new approach of evolutionary developmental biology or evo devo Key themes include the following developmental repatterning adaptation and coadaptation gene co option developmental plasticity the origins of evolutionary novelties and body plans and evolutionary changes in the complexity of organisms As can be seen from this list the book includes information across the levels of the gene the organism and the population It also includes the issue of mapping developmental changes onto evolutionary trees The examples used to illustrate particular points range widely including animals plants and fossils I have really enjoyed reading this book One of the strengths of the book is the almost conversational style I found the style easy to read but also feel that it will be invaluable in teaching One of our tasks in university level teaching is to develop students critical thinking skills We need to support them in their intellectual development from a just the facts approach to being able to make critical judgements based on available evidence The

openness and honesty with which Arthur speaks to uncertainty in science is refreshing and will be a baseline for discussions with students Professor Patricia Moore Exeter University This book written as an undergraduate text is a really most impressive book Given the burgeoning interest in the role of developmental change in evolution in recent times this will be a very timely publication The book is well structured and like the author s other books very well written He communicates with a clear lucid style and has the ability to explain even the more difficult concepts in an accessible manner Professor Kenneth McNamara University of Cambridge The companion site can be found at www.wiley.com/go/arthur/evolution Here you download all figures from the book captions tables and table of contents

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Phenotypic Plasticity Thomas J. DeWitt, Samuel M. Scheiner, 2004 Genetic evolution adaptation environment genotype

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New Directions in Theology and Science Peter Harrison,Paul Tyson,2022-01-31 This book sets out a new agenda for science theology interactions and offers examples of what that agenda might look like when implemented It explores in innovative ways what follows for science theology discussions from recent developments in the history of science The contributions take seriously the historically conditioned nature of the categories science and religion and consider the ways in which these categories are reinforced in the public sphere Reflecting on the balance of power between theology and the sciences the authors demonstrate a commitment to moving beyond traditional models of one sided dialogue and seek to give theology a more active role in determining the interdisciplinary agenda

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