



02 March 2012

Mechanisms of Life History Evolution: The Genetics and Physiology of Life History Traits and Trade-Offs

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23 February 2012

Variations on evolutionary themes

Editors: Thomas Flatt and Andreas Heyland

Edition: First

Publisher: Oxford University Press

Pages: 504

Price: £80.00 and £45.00

ISBN: 9780199568765 and 8772

I was a PhD student when Mosaic - the first graphical interface to the internet - emerged, at a time when synthetic books on major themes in ecology and evolution were still required reading. I recall the first few Princeton University Press monographs I purchased, and the early financial constraints that forced me to decide whether to buy first Derek A. Roff's *The Evolution of Life Histories: Theory and Analysis* (1992) or Stephen C. Stearns' *The Evolution of Life Histories* (1992). Such books provided historical frames of reference, reference lists to search through, and the opportunity to find gaps in knowledge on which to plan future careers.

Of course all that changed with the internet. Hyperlinks, referencing software and webs of knowledge are the new library, and we often seem to prefer the gentle warmth of a browser to the pages of a journal or a book. However, Thomas Flatt and Andreas Heyland's *Mechanisms of Life History Evolution: The Genetics and Physiology of Life History Traits and Trade-offs* single-handedly kept me off a computer for a long time and renewed my excitement about books.

Flatt and Heyland have clearly spent much time editing this book and have produced an effective template for an impressive set of authors, organised contributions into coherent sets with logical flow, and offer their own preview of each section. This provides readers with multiple points of access to the material.

The content is motivating. Evolutionary ecology is slowly embracing the possible merits of the genome revolution. The 25 chapters in this book shed light on many advances made in linking tissue-specific and temporal patterns of development that govern intra- and inter-specific variation to gene expression and the endocrine physiological pathways they regulate. We are reminded repeatedly that life history variation requires mechanisms that allow for temporal and spatial variation in development; that resource allocation alone may not underpin trade-offs; and that conservation of genetic and physiological function can be interpreted differently within and between species. It all feels important!

But will it change anything? For some, the most compelling aspects of this book will be the pair of chapters where Stearns and the editors argue over the merits of this "molecular natural history". Is Stearns right to argue that these 25 chapters of molecular natural history are not yet effective because they fail to overturn any of the synthetic, simplifying theory on which our understanding of life history evolution is based? Although these chapters make for one of the most exciting exchanges in print for a long time, do your utmost to read it last, not first! The core chapters help us think, across the breadth of organisms, about how the molecular natural history of life histories affects life history theory, evolutionary theory, ecological theory and whether (or when) it might reveal new patterns that require new theory.

Who is it for? Evolutionary ecologists looking for some molecular biology and molecular biologists looking for some evolutionary ecology.

Presentation: Well-structured compilation from field leaders with a real "discussion" at the end.

Would you recommend it? Excellent chapters, sections and overview by the editors will turn this book into a much-read, dog-eared reference staple. Highly recommended.

Reviewer :

Andrew P. Beckerman is senior lecturer in evolutionary ecology, University of Sheffield.



CHICAGO JOURNALS

Mechanisms of Life History Evolution: The Genetics and Physiology of Life History Traits and Trade-Offs edited by Thomas Flatt and Andreas Heyland

Mechanisms of Life History Evolution: The Genetics and Physiology of Life History Traits and Trade-Offs by Thomas Flatt; Andreas Heyland

Review by: Mark Viney

The Quarterly Review of Biology, Vol. 87, No. 3 (September 2012), pp. 255-256

Published by: [The University of Chicago Press](http://www.uchicago.edu)

Stable URL: <http://www.jstor.org/stable/10.1086/666772>

Accessed: 19/08/2012 04:16

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as medical professionals, becoming regional experts at the expense of studying the head in its entirety. This is where Lieberman's book comes in, and it is why this volume will be viewed as an important contribution to the anatomical and anthropological literature for years to come.

The Evolution of the Human Head is an engaging synthesis of anatomy, evolutionary biology, developmental biology, and paleontology in an effort to understand the evolution of our distinctive skull. Lieberman's thesis is that, precisely because of the skull's integration and overall complexity, relatively small changes during development ("tinkering") have cascading consequences and result in relatively large changes in the overall form of the human head. The author argues for just these sorts of changes during human evolution, and he connects these small developmental changes to selective advantages for walking and running bipedally, chewing and processing different types of food items, and increasing brain size. Add these small changes up over five to seven million years and Lieberman illustrates that it is not terribly difficult for natural selection to transform a chimpanzee-like head into one as unique as our own. In fact, as the author demonstrates, many aspects of fossil hominin crania hint at periods in time when some of these developmental changes were occurring. All in all, this is an amazing review of human cranial anatomy, development, and integration that allows a broader perspective on how the skull evolved.

CHRISTOPHER C. GILBERT, *Anthropology, Hunter College, City University of New York, New York, New York*

PLASTICITY, ROBUSTNESS, DEVELOPMENT AND EVOLUTION.

By Patrick Bateson and Peter Gluckman. Cambridge and New York: Cambridge University Press. \$115.00 (hardcover); \$45.00 (paper). ix + 156 p.; ill.; index. ISBN: 978-0-521-51629-7 (hc); 978-0-521-73620-6 (pb). 2011.

As encapsulated in their concluding sentence, which extends Dobzhansky's famous quote to "[n]othing in biology makes sense except in the light of evolution and development" (p. 132), Bateson and Gluckman's short book is a plea for biologists to more seriously consider developmental processes, moving away from gene-centric views of individuals and evolution. This volume argues that the nature-nurture dichotomy, and the metaphor of the "genome as a blueprint," are impediments to scientific progress. They replace such dichotomies and metaphors with a clear framework that articulates how integrated and functional phenotypes arise from genomes in the face of environmental variation and perturbation. The authors argue that genes and

environment cannot (and should not) be separated when studying phenotypic evolution; indeed, the genotype-by-environment interaction is a tool to study sources of variation in populations, not a conceptual framework to approach development. Similarly, there are no genes "for" a trait; instead, hundreds of genes may underlie the development of a trait, while a handful of genetic differences may explain variation in a trait. They discuss how robustness and plasticity are not separate, but intertwined, given that plasticity often underlies robust phenotypes, and many induced, plastic phenotypes are robust. The authors also clearly lay out the links between development and evolution, reviewing the importance of robustness and plasticity for the survival of organisms and stabilization of phenotypes in novel and changing environments until a phenotypic change is fixed through selection on development. Throughout the book, the authors clarify a long list of concepts—such as robustness, plasticity, and modularity—integrating them and clearly illustrating their diverse mechanistic bases, such as epigenetic-induced changes in gene expression. Bateson and Gluckman's complementary perspectives result in clear, powerful, and accessible arguments. The framework developed in this volume is timely, refreshing, informative, and easy to read for not only biologists and doctors, but also the general public.

EMILIE C. SNELL-ROOD, *Ecology, Evolution & Behavior, University of Minnesota, St. Paul, Minnesota*

MECHANISMS OF LIFE HISTORY EVOLUTION: THE GENETICS AND PHYSIOLOGY OF LIFE HISTORY TRAITS AND TRADE-OFFS.

Edited by Thomas Flatt and Andreas Heyland. Oxford and New York: Oxford University Press. \$144.00 (hardcover); \$79.95 (paper). xxv + 478 p.; ill.; index. ISBN: 978-0-19-956876-5 (hc); 978-0-19-956877-2 (pb). 2011.

Life-history theory successfully explains why different species live the lives they do. It has been powerful in showing that the diverse life histories of different species can be understood as the result of one underlying evolutionary process. That said, how, mechanistically, life histories are controlled (and so how they evolve) is not known. Life-history theory can proceed apace without knowing these mechanisms, although this theory does use conceptual mechanisms all the time; for example, recognizing that there are constraints to, and trade-offs between, life-history traits. This book, a collection of 28 multiauthor chapters is an ambitious, first attempt to capture the state of the art of progress in understanding mechanisms of life-history traits. The volume has an impressive range (covering animals and plants, although taxonomically, the arthropods dominate), arranged into seven parts, with the central five sec-

tions focused on key aspects of life-history biology: growth; reproduction; lifespan; plasticity; and trade-offs. The editors do an impressive job of bringing coherence to the structure of every chapter as well as an introduction to each section. The book is topped and tailed by an introductory call to arms and a concluding critique.

Although this book is the state of the art of understanding mechanisms of life-history biology, it makes clear the difficulties for this field. I think there are at least four. First, life-history traits are complex, and so will be their underlying genetics. Genetics and genomics have, to date, sought to explain how genes control phenotypes. It has done this successfully, but only for simple traits, simple in the sense that there is a clear one gene-one trait relationship. Our ability to now collect genome sequence data (and ever more quickly and cheaply) has made clear that we have very little idea what most of an organism's genes are doing. This is fair enough because these are early days in this endeavor. To my taste, it seems that we keep busy collecting ever more genome sequence data so as to avoid having to think about what to do with it to gain biological insight. The justifications often seem to be that, perhaps, if we have just a bit more data then clarity may dawn (why?), or this will be a good community resource (but for what?), but that we need better taxonomic representation (ok, but what for?). Moreover, for even slightly complex traits, it is combinations of genes in networks that are relevant, and these are much harder to study (Banta and Purugganan's Chapter 9 gives an idea of how these studies might look). Life histories are complex traits; in fact, they are likely a complex of subtraits and need to be treated as such. Treating them in this way might clarify whether or not apparently analogous traits among species are, indeed, the same or not. For example, diapause in some form occur in many taxa, but are insect diapause really the same as mammalian hibernation? Therefore, correct identification of the subtraits of life histories and recognizing that they will have complex genetic control will be key to progress.

Second, candidate gene approaches, but what about the rest of the genome? We know that all life is related, so it is clear that often similar genes will be performing similar processes in related species. It is relatively easy to generate data consistent with such ideas, although often the extent of the proof is less than one would like. Candidate gene approaches (i.e., starting from a well-studied gene in species 1, find the homologous gene in species 2 and seek to show conserved function) are biased because they are effectively ignoring most of the genome. Even for the most thoroughly studied model organisms (*D. melanogaster*, *C. elegans*) we have no idea

of what most of the genes do (the full range of genes may be computationally predicted, and their similarity to genes in other organisms known, none of which really helps with understanding function). These neglected genes are hard to work on, but it has to be that many of them will be involved in these two complex traits in which we are interested. More generally, this argues that a quantitative genetic approach to life-history traits is needed. These approaches are unbiased in their search for genetic control and are bound to illuminate dark corners of genomes.

Third, a confusion between studying the signal and the information content of the signal. Many of the chapters of this book look at hormonal control of traits, leading to the superficially attractive conclusion that hormones are key mediators of life-history traits. Really? Hormones are the means by which large multicellular organisms pass information around their bodies. If you take a computer to pieces, you will find it is full of electricity—this is how information is moving around your computer. Hormones/electricity are the messengers, not the message. The key to understanding the mechanisms of life histories is to know what those hormones are saying, to whom and when. Therefore, surely the question becomes when is a hormone signal turned on and off, and where, and when and where is that signal received and what is the consequence?

Finally, let us study resource allocation—properly. Trade-offs and constraints are key to almost all our thinking about life-history traits. These are most often thought of as questions of resource allocation, for example, the Y-model where limited energy (bottom of Y) can go to reproduction or survival (the two tips of Y; Lancaster and Sinervo's Chapter 25 explores this extensively). This is a conceptually important and clear mechanism that can be tested. Therefore, tracing energy/micronutrients from organismal acquisition to use for a trait would seem to be the most direct and powerful approach to use. This approach is barely being used (Zera and Harshman's Chapter 24 being a notable exception), but should this not become mainstream?

Are these reasons to give up and be downhearted? Absolutely not, it is a reason to redouble our efforts, but recognizing that investigating and understanding mechanisms of these important, complex life-history traits is a major intellectual challenge (and more so intellectual than technological) that may be the next great leap forward in biology. So remember, it started here first with this book.

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A Tour of the Senses: How Your Brain Interprets the World By John M. Henshaw. 288 pp. Baltimore, MD: Johns Hopkins University Press. 2012. \$29.95 (cloth).

A Tour of the Senses is a fun grab-bag of a book. Opened to almost any page, it contains some interesting fact or statistic, presented in a clear and accessible style. Henshaw is a Professor of Mechanical Engineering at the University of Tulsa and targets his book at a very general audience, the sort of readers whose first reaction will be that he is “a bit of a wacko” (pg. 6) for claiming (correctly) that we have more than five senses. As an introduction to sensation for a general audience, the book works reasonably well. It provides a gentle and entertaining introduction that is never dull and in places highly compelling.

Henshaw’s background as an engineer (rather than a neuroscientist or psychologist) is apparent in his overall approach to sensation, which presents the senses as a collection of gadgets such as might be found in a fancy new car or tablet computer, so many accelerometers and pressure transducers, thermometers and gyroscopes. As a matter of exposition, there is much to be said for this approach, and it certainly plays to Henshaw’s strengths as a writer. He clearly has a knack for describing how things work and his descriptions of the physical substrate of sensory stimuli and the mechanics of the sensory receptor organs are fine examples of clear technical writing and form the highlights of the book. Particularly enjoyable are the descriptions of the middle ear and cochlea, underlying the sense of hearing, and of the vestibular system, mediating the sense of balance and spatial orientation.

A Tour of the Senses is divided into three broad sections on “Stimulus,” “Sensation,” and “Perception.” The section on Stimulus describes the different types of physical stimuli that we are able to sense, with chapters on Electromagnetic, Chemical, and Mechanical stimuli. The second section on Sensation describes how the different sensory organs convert these stimuli into electrical nerve signals. The final section on Perception describes how the brain interprets these signals. The separation of the latter two sections on Sensation and Perception is traditional and mirrors the approach of most textbooks on the topic. The inclusion of an entire section on Stimulus, however, is a surprising choice, and unfortunately mostly unsuccessful. Because the sensory organs are (as Henshaw argues) essential devices that convert physical stimuli into electrical nerve signals, there is an intimate link between the nature of the stimulus and the nature of the organ. The second section, on Sensation, thus, feels somewhat repetitive. For example, we learn about the physical nature of light in Chapter 1 (“Electromagnetic Stimuli”) but then have to review this material when we get to Chapter 5 (“Vision”), making the three intervening chapters seem like a detour.

On the whole, the sections on Stimulus and Sensation provide a good, clear overview of sensation. These sections alone may make the book worthwhile for readers unfamiliar with the topic. The final section on Perception, however, works less well and may simply leave readers confused about what the key issues even are. In Chapter 8 (“Remembering the Present”), Henshaw describes the brain mechanisms involved in constructing full conscious percepts from sensory inputs. Though the book is subtitled

“How your brain interprets the world,” it feels as though Henshaw is out of his depth here. He introduces the reader to the idea of neurons and synapses and gives some impressive statistics about neuron connectivity, then abruptly drops the topic. It is surprising at this point that the concept of receptive fields of sensory neurons is not introduced, nor anything about topographic maps in the sensory cortices, nor anything about what is known about neuronal computation such as the classic and Nobel Prize winning studies of David Hubel and Torsten Wiesel (1998). Thus, on the whole, the Perception section flits from topic to topic, leaving each only partly developed. Certainly, any full coverage of these issues is beyond the scope of a book intended for a general audience. The patchy coverage of key issues, however, is all the more mystifying given curiously extended detours, such as fully half of Chapter 9 on “Perception and Culture” being given over to a discussion of the economics of food portion size. On the whole, this section feels cobbled together out of odds and ends, each being interesting enough on its own, but which do not come together to provide any coherent story about how perception works. Though some excellent examples are given, such as the demonstration of perceptual “filling-in” of the blind spot on the retina, the reader is not given sufficient theoretical depth to interpret them, so that they come across as mere curiosities.

A Tour of the Senses is a fun book, which may be of interest to anyone who’s ever wondered how the eye or the ear works. As an introduction to one of the central fields in Psychology and Neuroscience, however, the book disappoints. This is a whistle-stop tour of the senses, which will be unlikely to interest anyone with more than a passing familiarity with sensation and perception.

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DOI: 10.1002/ajhb.22322
 Published online 5 October 2012 in Wiley Online Library (wileyonlinelibrary.com).

Mechanisms of Life History Evolution: The Genetics and Physiology of Life History Trade-offs. Edited by Thomas Flatt and Andreas Heyland. xxvii + 478 pp. New York, NY: Oxford University Press. 2011. \$144.00 (cloth), \$79.95 (paper).

In my initial reading of *Mechanisms of Life History Evolution*, I was somewhat frustrated by the time I finished the first of a pair of chapters comprising the Concluding Remarks. The first remarks chapter calls evolutionary developmental biologists to the carpet to pay more attention to life history theory. My concern gave way to great enjoyment because of the rarely seen lively exchange across both concluding chapters between Stephen Stearns (whose works are cited many more times throughout this

volume than even he notes) and the editors regarding the state of the field and how mechanistic studies are (or are not) contributing to advance life history theory. There is exciting insight here and it greatly improved my rereading of the book. The arguments are nuanced and interesting in terms of a voiced debate between theorists and evolutionary ecologists. Although the 25 chapters that precede this discussion form the basis for both arguments, I would recommend being a spoiler—read this first to provide additional context to the excellent survey of organismal experiments and observations regarding how physiology, development, and gene expression affect life history variation and evolution.

Flatt and Leyland are careful to outline through the Foreword (written by Graham Bell), Preface, and first two chapters the topic at hand: how do genotype-to-phenotype relationships affect evolutionary outcomes? The introductory materials are followed by a collection of organismal studies—grouped into five topical sections—addressing aspects of life history evolution with something for everyone. The writing throughout these sections is excellent; the expertises of the chapters' authors shine through and are accessible to a broad audience with training in molecular techniques and evolutionary trajectories.

The editors also challenge the reader by including experimental evidence that both supports and confuses our current understanding of the trade-offs regarding evolutionary constraints on life history evolution, which is exciting and promotes thinking about future experiments as well as providing the basis for in-class activities at the graduate level. I believe the strength of this book lies precisely in its ability to get a broad group of disciplines thinking about how to improve our under-

standing of life history evolution from the species level all the way up to broad theory. Although there is somewhat of a bias toward a few model organisms, where possible, the authors have included a broad taxonomic sampling, including some of the most up to date genomic information available (e.g., the chapter concerning multicellularity). I would not recommend this book as a teaching tool for undergraduates due to the complexity of the introduction chapters and the need for a fairly deep understanding of life-history strategies before utilizing this book; however, I do think it would be an excellent book to work out of for graduate students as well as researchers interested in ecological and evolutionary genomics.

“While impressive progress is here reported on our understanding of the mechanistic basis of life history variation, this volume should be taken as an intermediate progress report... (p. 373).” Rather than this being a shortcoming of mechanistic studies, I would argue that this statement speaks to the strength of this volume, in that it is a great jumping off point for new investigations and an exchange of ideas within and between groups of theorists and experimental biologists alike.

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DOI: 10.1002/ajhb.22323

Published online 25 September 2012 in Wiley Online Library (wileyonlinelibrary.com).

BOOK REVIEW

Life-history evolution: understanding the proximate mechanisms

Mechanisms of life history evolution

Thomas Flatt and Andreas Heyland

Oxford University Press; 2011; XXIV+478 pages; US\$79.95; ISBN 978-0-19-956877-2

Reviewed by N. G. PRASAD*

Several years ago as a fresh graduate student in a laboratory focussed on life-history evolution, I was required to write a term paper for a course on 'Advanced evolutionary biology'. Having worked in the laboratory for about six months and read through numerous papers on life-history evolution, I was convinced that nothing in life-history was more important than 'trade-offs'. So, I choose to write my term paper on trade-offs in life-history evolution. In the course of writing that term paper I realized that while studies had established the ubiquity and importance of trade-offs through a multitude of approaches, there was frustratingly little material about the proximate causes of such trade-offs. The general assumption in most studies was that trade-offs were somehow related to the partitioning of limited resources. Now, after several years of having read the book edited by Flatt and Heyland, I wish that I had access to this excellent book as a fresh graduate student! For this book does something that has long been overdue—try and bridge the gap between the ultimate and proximate explanations of life-history evolution.

Life-history, the timing of onset and distribution of reproductive output of an organism over its entire lifespan is of central importance in evolutionary biology since it is the life-history that forms the interface between an organism and its Darwinian fitness. Life-histories are extremely variable within and across species and explaining such variation is the primary goal of research into life-history evolution. Research within this area focusses on life-history traits such as age-specific mortality and fecundity which are directly related to the fitness of the organism and several other life-history related traits that are only indirectly related to fitness. Previously several books have synthesized the research in this field from the point of view of ultimate questions. The present

book, however very clearly has a different agenda. It synthesizes the present understanding of life-history variation from a mechanistic perspective.

Over the last several years, information about mechanisms has been generated by people working in various fields and model organisms. Very aptly, the present book represents a synthesis across various approaches such as developmental biology, demography, endocrinology, immunology, anthropology, molecular genetics etc. In terms of organisms, information is synthesized across algae, plants, worms, insects, lizards and humans. All this synthesis happens across 28 chapters distributed into seven different parts with each part addressing an important aspect of life-history evolution. It is interesting to note that the largest part (with about 100 pages) is the one addressing trade-offs. The chapters are carefully written and are a wealth of information. They not only synthesize the current understanding but also suggest future directions of research. Also, each chapter has a pointwise summary to round it off. Wherever relevant, the chapters are cross referenced within the book, thus holding the book together more tightly. Each part starts with a helpful introduction by the editors which serves to integrate the chapters within each part as well as different parts together. In the last part of the book, S. C. Stearns in an extremely well-written and thought-provoking chapter synthesizes the entire book, which is followed by an equally interesting exchange between the editors and Stearns.

So, does this book add any value to the field of life-history evolution? Definitely yes! To me, the book is a must read for three reasons: (i) it collates the proximate causes of life-history variation in a wide variety of taxa. While the general framework of life-history theory guides majority of research in the area, an understanding of the underlying mechanisms that bring about such variation in life-history related traits is important to better appreciate the nuances of life-history evolution. For example, while it had been predicted that rapid preadult development would lead to a competitive advantage, in *Drosophila melanogaster*, it has been

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Keywords. life-history; trade-offs; hormonal regulation; resource allocation; signalling.

found that rapidly developing larvae are at a competitive disadvantage (Shakarad *et al.* 2005). Sometimes the explanation of such unexpected results is possible only if one looks at the mundane mechanics of food acquisition and utilization.

(ii) The book collates some surprising results that question our long-held assumptions about life-history evolution. There are at least two such observations. First, for a long time, it has been assumed that physiological trade-offs are resource based. However, several chapters in this book raise the possibility that this might not be the case always. At least in some cases, trade-offs can be caused by signalling networks with or without the involvement of resource partitioning. It is quite possible that the mediation of a trade-offs is environment specific thereby explaining the absence of well characterized trade-offs in some environments. Second, some features of the signalling pathway that seems to mediate trade-offs in life-history traits seems to be shared across taxa.

(iii) Hormones are recognized as important mediators of physiology in terms of growth, resource allocation, repro-

duction and ageing, and are expected to be important in life-history evolution. The book has a series of chapters on the role of hormones in mediating life-history which help develop a view of the mechanistic relationships between life-history traits (as opposed to the genetic architecture of fitness components developed by classical studies).

As Stearns and the editors point out, the study of mechanisms underlying life-history variation is still in its infancy and much needs to be done before one can start integrating mechanisms with life-history theory. However the present book does an admirable job of consolidating the present state of knowledge in the field. To sum up, this book is required reading for people working in the area.

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"This book is a fantastic resource for anyone interested in life history. My own research is moving from behavioural ecology into a more detailed examination of the mechanisms underlying life history trade-offs and I found fascinating insights into the field of life history. The chapters are detailed enough to satisfy me as an experienced researcher, but also would offer a wonderful introduction to graduate students or early career scientists wanting to engage in this field of study. I particularly liked the concluding chapters, which provide insight into the challenges that lie at the intersection between molecular mechanisms and evolutionary outcomes. I am certain that this book is one that will be frequently pulled off my shelf as I work to design and understand my experiments." - **Professor Patricia Moore, University of Exeter, UK**

"Flatt and Heyland's exciting new volume gives a rich harvest of current work on life history evolution across the Animal and Plant kingdoms. Wisely, the editors included several chapters discussing human biology. The diverse species discussed should catalyze biomedical researchers to look beyond the standard animal models of fly, worm, and mouse. Inclusion of diverse life history paradigms will be essential to developing the genomics of life history evolution." - **Professor Caleb E. Finch, University of Southern California, USA**

"An expanded modern synthesis of evolutionary biology, which truly integrates ecology, evolution, and development, is on the horizon. This edited volume brings together an impressive team of scientists from diverse fields in an attempt to integrate recent advances in molecular and developmental biology with traditional life history theory. In so doing, this volume will not only inspire a better understanding of the evolution of development, but will also inspire revisions and advances in traditional life history theory, and thus, take us one step closer toward achieving an expanded evolutionary synthesis." - **Professor Ehab Abouheif, McGill University, Canada**

"Flatt and Heyland have solicited contributions from an impressive array of researchers studying the mechanisms of life history evolution in organisms ranging from algae to humans. This timely volume not only provides a snapshot of our current understanding of the genetic, physiological, and developmental mechanisms of life history evolution, but also points the way toward a promising integration of theoretical and mechanistic approaches to the study of life history evolution. As such, this book complements our understanding of the principles of life history evolution by revealing the diverse and sometimes constraining tools that organisms have evolved to solve their unique ecological puzzles. This comprehensive treatment of the mechanisms of life history evolution is sure to become the subject of many graduate seminars and will be a welcome companion to classic texts on life history theory on comprehensive exam reading lists." - **Professor Andrew McAdam, University of Guelph, Canada**

"For years there has been a divide between biologists that asked why and those that asked how. This book integrates the two perspectives beautifully, while addressing the most fundamental of all aspects of an organism - its life history. Here we learn how adopting genetic, genomic, and physiological perspectives informs evolutionary patterns of birth, growth, reproduction, ageing, and death. This book comprehensively reviews and informs us about the latest developments in mechanistic and evolutionary approaches to understanding the diversity of life history patterns in nature. With chapters by the authorities and innovators in the field, this is a work that will inform and inspire my laboratory for years to come." - **Professor Allen J. Moore, University of Exeter, UK**

"This edited volume provides a fresh and much-needed update to the venerable field of life history evolution by emphasizing the importance of understanding its underlying genetic and molecular basis." - **Professor Gregory Wray, Duke University, USA**

"In this impressive and substantial edited work, Thomas Flatt and Andreas Heyland have gathered together contributions from numerous authors, many of them leaders in their fields, all aimed at a common goal: the integration of a mechanistic component into life-history theory. Although, as the editors state, this integration is still in its infancy, the volume they have assembled will help enormously in the growth of the infant concerned, which in turn will help in the further integration of evolutionary biology as a whole." - **Professor Wallace Arthur, National University of Ireland, Galway, Ireland**

"Many of us excited about the long overdue synthesis of development and evolution were nevertheless a little disturbed by its lopsided nature, exemplified by an almost exclusive focus in 'evo-devo' on the evolution of mechanisms directing the ontogeny of form. It was argued that we also need a rich 'devo-evo' focusing on understanding the developmental underpinnings of microevolutionary change. The compilation by Flatt and Heyland is thus especially timely as it fills this long-standing lacuna in the balanced integration of ecology, evolution and development. The book brings together well written chapters by many leading experts, covering mechanisms of life-history traits and trade-offs in a range of organisms from algae to angiosperms and cnidarians to humans. Unlike in many compilations, the broader issues and questions are always in sight. Section headers that thread together related chapters do a great job of putting the issues in a more

general conceptual context, something that will be particularly helpful for graduate students. Towards the end, there is also a good discussion of how understanding mechanisms affects or does not affect the theory of life-history evolution, with some thought being given to how experimental work into mechanisms might be designed to better integrate with theoretical concerns and vice-versa. This section, in fact, could ideally have been longer with a greater diversity of view-points especially from quantitative genetics. I can imagine this book being a superb resource for established researchers and graduate students alike. I plan to make a discussion of major parts of this book the focus of my advanced seminar course on evolution next year." - **Professor Amitabh Joshi, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India**

"This volume contains an impressive amount of information about the molecular and physiological mechanisms behind life-history trade-offs, with contributions from leading authors in the field. It should be an excellent entry to this vast literature for those who wish to bring the field further and wish to understand how organismal life-histories evolve and the factors that constrain them. The book also includes a critical discussion about the utility of mechanistic knowledge in the development of life-history theory; here radically different viewpoints are contrasted against each other. I recommend this book to those who are interested in this classical field and the many controversies surrounding it." - **Professor Erik Svensson, Professor in Evolutionary Ecology, Lund University, Sweden**