

## Biased Embryos and Evolution

What determines the direction of evolutionary change?

This book provides a revolutionary answer to this question. Many biologists, from Darwin's day to our own, have been satisfied with the answer, 'natural selection'. Professor Wallace Arthur is not. He takes the controversial view that biases in the ways that embryos can be altered are just as important as natural selection in determining the directions that evolution has taken, including the one that led to the origin of humans. This argument forms the core of the book. However, in addition, the book summarizes other important issues relating to how embryonic, and post-embryonic, development evolves.

Written in an easy, conversational style, this is the first book for students and the general reader that provides an account of the exciting new field of evolutionary developmental biology ('evo-devo' to its proponents).

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Stephen Jay Gould once said that *the most noble word of all human speech* is ‘*teacher*’. In the spirit of that remark, I dedicate this book to all of my teachers across the years, and in particular: my mother, my father (*in memoriam*), Amyan Macfadyen, Bryan Clarke, Alec Panchen, and, during an all-too-brief period of sabbatical leave spent at Harvard in 1987, SJG himself. I thank you all.

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## Preface

The processes of life work at many different speeds. Some occur swiftly, others require millions of years; some recur in a cyclical manner, others are historically unique. The two great processes of biological creation are embryological development and organic evolution. Development fits into the rapidly recurring category, while evolution fits into the complementary category of the unique and time-extended.

However, in the world of life, always beware of generalizations. It is science's duty, and its pleasure, to attempt them; but they are often wrong or, at the very least, subject to some ifs, buts, and exceptions. It takes a long time to develop a blue whale or a Californian redwood from a fertilized egg. That space of years is more than enough for a microbe with a generation time of half an hour to evolve resistance to penicillin. So the developmental and evolutionary timescales overlap, but not by much.

Both of the two great processes of biological creation have their historical heroes, though those of evolution tend to be better known than those of development. Darwin and Wallace spring more readily to most layminds than Fabricius or Roux. The heroes of genetics are important too, as genes underlie both processes; so we are also indebted to Mendel, Watson and Crick.

But I am more concerned here with the present and the future than with the past. For a quiet revolution is beginning in biology, and as yet its heroes are relatively unsung. While studies on development and on evolution were carried out in relative isolation for most of the twentieth century, today there is a thrust towards synthesis. A new interdisciplinary field is emerging, which goes by

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the odd shorthand name of ‘evo-devo’, largely because its full title – Evolutionary Developmental Biology – is rather cumbersome.

How can the small and rapid be productively united in a conceptual way with the grand and slow? What do embryos tell us about evolution, or vice versa? Is this a great leap for biology or just another step? These are the questions I try to answer herein.

Some of the answers that I give to these and related questions are the same as those that most other biologists would give. Here, we are in the realm of well-established ‘facts’. But some of my other answers are new and/or controversial. In particular, the core of the book deals with a single, controversial question of the utmost importance: do biases in the ways in which embryos and other developmental stages can be modified provide a sort of internal ‘direction-finder’ to the process of evolution that interacts with its external equivalent, namely natural selection? This question first arises in Chapter 2, and is explored in detail in Chapters 7, 8 and 9. Its ramifications are considered later, especially in Chapters 16 and 17.

It is this core question – and my proposed answer of ‘yes’ to it – that gives the book its name. But notice that a complication has already crept in here in the form of ‘other developmental stages’. The idea of biased developmental variation extends beyond the embryo, to all post-embryonic stages. So I have undersold myself in the title; but then again ‘*Biased embryos, larvae, juveniles, adolescents, etc.*’ lacks a certain style.

It is more conventional to put forward new scientific ideas in the specialist literature. And indeed I have given technical accounts of developmental bias and the other controversial ideas discussed herein in the appropriate biological journals. But I couldn’t resist the challenge of trying to make these important ideas accessible to a wider audience, which is the aim of this book. I have written it in a way that I hope will maximize my chances of achieving this aim. So there are no Latinized species names, no mathematical models, and only minimal genetics. The book is short; so are most of the

individual chapters. The writing style is casual. I have written the text as if it were a conversation. There is no stale scientific passive, which is increasingly out of favour anyhow. I have also thrown in a few anecdotes about my own life, where these help to introduce a particular topic in a reader-friendly way. I have avoided jargon wherever possible, but have included a Glossary to cover things that I don't think of as jargon but you might.

So I hope that the book will be accessible to biologists and non-biologists alike, though the former may wish to 'fast-forward' through some of the introductory material (in particular, developmental biologists may wish to skip Chapter 4 and evolutionary biologists Chapter 5). Equally, I hope the book will be accessible to everyone from first-year undergraduates (in any subject) through to emeritus professors. Not just accessible, but interesting too, and perhaps, in just a few places, awe-inspiring. If new ideas about the relationship between the two great processes of biological creation cannot inspire awe, what can?



## Acknowledgements

Many people have generously given their time to read successive drafts, of which there have been quite a few. Generally speaking, the more reactions an author takes account of before finalizing a script, the better it becomes. In this case, I have been careful to take on board comments made by both specialist and non-specialist readers, in order to try to cross that dangerous rope-bridge between the twin chasms of inaccuracy and unreadability, without falling off in either direction.

So, I would like to thank all of the following for their noble efforts in helping me perform this balancing act. However, I should add that if my belief that I have not plunged into either chasm is perceived by later readers to be misguided, then they know full well where the ultimate responsibility for a book lies, and it is clearly not with those whom I now thank: Chris Arthur, Jack Cohen, Ward Cooper, Richard Gordon, Kenneth McNamara, Alec Panchen and Mary Scott.

Although I very much enjoy writing, especially when it 'flows', I am also a firm believer in the saying that 'a picture is worth a thousand words'. As ever, there is an issue of balance here, and if I had published *Biased Embryos and Evolution* as a 'picture book', few if any would have taken it seriously. But it would have been a drier affair altogether without the many illustrations that are scattered through it and that, I hope, make some of the ideas 'come alive'. For their design and execution I thank Raith Overhill and Tracey Oliver.

Finally, although it is less common for the authors of books to acknowledge sources of funding than it is for the authors of primary scientific papers – since book authors are rarely funded in advance by anyone other than their publishers – there is one organization that I

would like to thank in this respect. In 1995, I was awarded a two-year Research Fellowship by the Leverhulme Trust. Although that was to write an earlier book (*The Origin of Animal Body Plans*, Cambridge University Press, 1997), I suspect that, had I not written that one, the present book would have been much impoverished, and indeed might never have appeared at all. This single piece of funding has had more far-reaching effects on my scientific thinking than all the other research funds that I have had over the years put together. Long may such schemes continue.