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## Understanding Evolution

Why do the debates about evolution persist, despite the plentiful evidence for it? Breaking down the notion that public resistance to evolution is strictly due to its perceived conflict with religion, this concise book shows that evolution is in fact a counterintuitive idea that is difficult to understand. Kostas Kampourakis, an experienced science educator, takes an insightful, interdisciplinary approach, providing an introduction to evolutionary theory written with clarity and thoughtful reasoning. Topics discussed include evolution in the public sphere, evolution and religion, the conceptual obstacles to understanding evolution, the development of Darwin's theory, the most important evolutionary concepts, as well as evolution and the nature of science. *Understanding Evolution* presents evolutionary theory with a lucidity and vision that readers will quickly appreciate, and is intended for anyone wanting an accessible and concise guide to evolution.

Kostas Kampourakis is the author and editor of books about evolution, genetics, philosophy, and history of science, and the editor of the Cambridge University Press book series *Understanding Life*. He is a former editor-in-chief of the journal *Science & Education*, and the book series *Science: Philosophy, History and Education*. He is currently a researcher at the University of Geneva, where he also teaches at the Section of Biology and the University Institute for Teacher Education (<http://kampourakis.com>).

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The ***Understanding Life Series*** is for anyone wanting an engaging and concise way into a key biological topic. Offering a multi-disciplinary perspective, these accessible guides address common misconceptions and misunderstandings in a thoughtful way to help stimulate debate and encourage a more in-depth understanding. Written by leading thinkers in each field, these books are for anyone wanting an expert overview that will enable a deeper understanding of each topic.

Series Editor: Kostas Kampourakis <http://kampourakis.com/>

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KOSTAS KAMPOURAKIS  
University of Geneva



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“While other books explain what is wrong with the popular attacks on evolution – e.g. creationism, or Intelligent Design – this concise book addresses the fundamental question: *why* do people fail to accept evolution? This is like going deep to the causes of the illness, while others just try to lower the fever.

Kampourakis argues convincingly that teleology, rather than theology, is the most important obstacle to understanding evolution. It is not just matter of science vs. religion.

This welcome book is a long overdue argument about the cultural and psychological roots of the widespread misunderstandings of evolution. It opposes scientism – the claim that evolution, or science in general, can bring an end to our questions, worries, and concerns; and, at the same time, it argues that evolutionary theory does not deprive our life of meaning.”

Alessandro Minelli, University of Padova, Italy, and author of *Plant Evolutionary Developmental Biology*

“A well-known philosopher of biology once wrote that evolutionary theory seems so simple that almost anyone can misunderstand it. In this heartfelt yet thoughtful book, Kostas Kampourakis essentially turns that sentiment on its head. The author’s words on philosophy and science may well lead readers to conclude that, although evolution can be counterintuitive and complex, almost anyone can understand it, with suitable reason and evidence. Kampourakis’ treatment should be especially enlightening for those who are wrestling with the acceptance of evolution as truth.”

John C. Avise, Distinguished Professor of Ecology and Evolution,  
University of California–Irvine, and author of *Evolutionary Pathways in Nature: A Phylogenetic Approach*.

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*"Understanding Evolution* by Kostas Kampourakis deserves a wide readership. It is a sensitive introduction to evolutionary theory itself, as well as its public image and its philosophical implications. It shows the very great importance of the father of the subject, Charles Darwin; sets the disputes with religion in context; and suggests that the evidence is overwhelming but that no reader need feel threatened. It is fair and comprehensive, lively without being heavy-handed, and judicious in its judgments. Read it yourself, and get a copy for your family and your friends!"

Michael Ruse, Florida State University, and editor of *The Cambridge Encyclopedia of Darwin and Evolutionary Thought*

" ... there are plenty of good books on evolution ... So why another one? Because, argues Kampourakis, *contra* a widespread assumption among educators, the biological theory of evolution is actually counterintuitive, and, if not properly taught, it immediately runs into incomprehension and generates conceptual confusion.... Scientific theories are dynamic, ever changing, perpetually incomplete and open to revision ... The more the public at large understands this, the better off we will be, and books like Kampourakis' certainly make a valuable contribution to nudging us in that desirable direction."

Massimo Pigliucci, K. D. Irani Professor of Philosophy,  
The City College of New York

"In *Understanding Evolution*, Kostas Kampourakis provides not only a masterly exposition of the elements of evolution but also a compelling explanation of why the topic is so difficult to understand. Informed by up-to-date biology as well as by state-of-the-art historical, philosophical, and psychological scholarship, the book is a concise and considered treatment that deserves the attention of anybody interested in evolution.

Glenn Branch, Deputy Director, National Center  
for Science Education

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“This is, without a doubt, the best book available that deals with what is often referred to as a straightforward dichotomy of ‘science versus religion.’ Not so is the central message of this outstanding, well-written and organized treatment of the nature of evidence, of theory – especially evolutionary theory – of the ramifications of evolution throughout society, and, perhaps most importantly, of why it is so difficult for so many to accept the evidence for evolution. Aimed at a general audience, this book should be read by all who struggle with the logic and consequences of the theory of evolution.”

Brian K. Hall, FRSC, University Research Professor Emeritus,  
Dalhousie University, Canada

“How extremely stupid not to have thought of that!”, Huxley exclaimed, when he first learnt of evolution by natural selection. But Darwin’s great insight is not at all obvious – in many ways, it is rather counterintuitive. The odds of experiencing that ‘Aha!’ moment are vastly improved by teachers like Kostas Kampourakis. Always attentive to conceptual obstacles, Kampourakis helps the reader to grasp the core of evolutionary theory – from evo-devo to genetic drift – to show just how rich and exciting it is.”

Tobias Uller, Professor of Evolutionary Biology,  
Lund University, Sweden

“In *Understanding Evolution*, the science educator Kostas Kampourakis offers an accessible but sophisticated analysis of the topic, combining historical, scientific, philosophical, and psychological factors. Though not ignoring religious concerns, especially those related to design, he focuses instead on the numerous difficulties associated with understanding evolution. Specialists and dilettantes alike will learn much from this volume.”

Ronald L. Numbers, Hilldale Professor Emeritus of the History of  
Science and Medicine, University of Wisconsin–Madison

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*“Understanding Evolution* is an outstanding resource for students, teachers, scientists, and journalists. It sets an impressive new standard for the field by integrating current findings from biology, psychology, and the philosophy of science. Using clear and compelling examples, Kampourakis uncovers the roots of our intuitions about the living world, and shatters widespread myths about why resistance to evolutionary ideas is prevalent. Readers will be rewarded with new tools for fostering scientific literacy, and fresh insights into one of the most profound biological ideas.”

Ross H. Nehm, Professor of Ecology and Evolution, Stony Brook University, and Editor-in-Chief, *Evolution: Education and Outreach*

“This volume addresses an important and timely issue – why does the concept of evolution encounter such resistance? – and provides a clear, original, and richly informative answer. Taking an interdisciplinary approach, the author reveals persistent conceptual obstacles that have broad implications for the nature of scientific understanding in the world today.”

Susan A. Gelman, Heinz Werner Distinguished University Professor of Psychology and Linguistics, University of Michigan, USA



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To my wife, Katerina, and our children, Mirka and  
Giorgos, for turning an inherently purposeless life into  
a deeply meaningful one.

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## Foreword

Back in 2014, Cambridge University Press published Kostas Kampourakis' original book *Understanding Evolution*. He wrote it as a textbook, aiming to bridge the gap between the concepts and conceptual obstacles to understanding evolution. The response was overwhelmingly positive, with enthusiastic endorsements from philosophers and historians of science, to biologists and science educators.

When Kostas and I came to discuss a potential new edition of his book, we agreed that it was important to ensure it was as widely accessible as possible. We discussed how we could achieve this and what the barriers to understanding were. From this emerged the idea of re-writing the book more fundamentally so that it would serve students, but also a broader, general audience. We agreed that the driving force of the book would be to identify and unpick the conceptual obstacles to understanding. From here arose our thinking of the potential value in applying this to a wide range of topics across the life sciences. And so the *Understanding Life* Series came to be.

Our vision for the series is to provide concise, accessible guides to key topics, written by leading thinkers in the field and focusing on the common misconceptions and misunderstandings that are potential barriers to gaining a deeper understanding.

The response from potential authors to this series concept has been wonderfully positive, as you will see from the list of forthcoming titles. We look forward to working with these authors and many more in the future, to bring you this series of exceptional titles. It is a joy to work with

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## xiv FOREWORD

Kostas Kampourakis on this series – his energy, ideas, insights and ability to tease out the barriers to understanding and learning on any given topic know no bounds.

Dr Katrina Halliday  
Executive Publisher, Life Sciences  
Cambridge University Press

## Preface: There is More to Resistance to Evolution than Religion

Evolutionary theory is the central theory of biology. It explains the unity of life by documenting how extant and extinct species share a common ancestry. It also explains the diversity of life by describing how species have evolved from ancestral ones through natural processes (a “species” can be defined as a group of individuals that can interbreed and produce fertile offspring, although this definition overlooks the complexities of microbial life). Today, an evolutionary perspective is dominant in many of the most active fields of biological research and also provides important insights in medical, agricultural, and conservation studies and applications. The evidence for evolution is vast and comes from several different disciplines, such as paleontology, systematics, developmental biology, and genomics, which makes scientists consider evolution to be a fact of life. All in all, evolutionary theory is a powerful scientific theory that organizes and provides coherence to our understanding of life. As Theodosius Dobzhansky, an important evolutionary geneticist of the twentieth century, famously stated, without evolution biology seems like a pile of sundry facts that make no meaningful picture as a whole.

Yet the idea of evolution has been, and continues to be, enormously debated in the public sphere. Various polls around the world have shown that there is a rather low public acceptance of evolutionary theory (discussed in Chapter 1), in many cases due to its perceived conflict with religious beliefs and worldviews (discussed in Chapter 2). Related to this is the relatively high acceptance of creationist ideas. In general, creationism is the belief that God created the universe, including the Earth and humans, through a series of miracles. Young-Earth creationists perceive the world to have been created in six days of 24 hours each, some time within the last 10 000 years, whereas

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Old-Earth creationists accept the scientific account of the age of the Earth but still believe that the creation of life took place through a series of miraculous interventions. A recent version of creationism is intelligent design (ID), the proponents of which consider, for instance, the vertebrate eye or the bacterial flagellum as irreducibly complex systems: they become non-functional if a part is removed. Therefore, they cannot have gradually evolved through evolution by natural selection, because any form lacking a part would be non-functional and would die out. Therefore, the argument goes, such systems can only have been created for their current roles by an intelligent agent, and so they stand as evidence for ID. As these arguments have been debunked repeatedly, I do not discuss them in the present book.

Many excellent books on evolution have been written, including sound arguments and suggestive evidence that shows not only that evolution is a fact of life, but also that evolutionary theory provides the best scientific explanation for all biological phenomena. However, the authors of most of these books seem to take for granted that it is simple for their readers to understand evolution. Therefore, it seems to be assumed that all people need are books that present arguments and evidence for evolution and/or against creationism. But if such books exist, why then do the public debates about evolution persist? Why is it the case that many people reject evolution or question its validity, despite the evidence for it and its enormous explanatory power in contemporary biological research?

In my view, there is a gap in the existing literature on this topic. Evolution is a rather counterintuitive idea (from a psychological point of view), and it should not be taken for granted that it is easy for all, or even most, people to understand it. There is ample research in psychology that supports the conclusion that resistance to scientific theories may be due to intuitions that generate preconceptions about the natural world, which in turn make scientific findings seem unnatural and counterintuitive. Such intuitions are never completely overwritten, despite even expert scientific knowledge. As a result, the preconceptions that people hold make evolutionary concepts difficult to understand. An additional problem is that people may misinterpret the implications of evolutionary theory for their lives, and may also extend these to questions beyond the realm of science. What is necessary is that people realize that evolutionary theory, like all scientific theories, is a means to understand the natural world, and nothing more. It is also a theory



that can be put to the test and not something to which we should dogmatically subscribe.

I have therefore written this book in an attempt to fill this gap in the literature, while also trying to present evolutionary theory in a comprehensible manner. To achieve this, I rely not only on evolutionary biology, but also on conceptual development research and on scholarship from both the history and the philosophy of biology. My main intention is to clearly describe the core concepts of evolutionary theory (in Chapters 5 and 6). However, before attempting this, I am being explicit about the obstacles that affect understanding of evolution (in Chapter 3), suggesting that the low percentage of acceptance of evolution is in part due to a lack of the required understanding. I also show that even Darwin himself had to undergo a process of conceptual change (Chapter 4). Thus, this book explains both what evolution is, and why it is difficult to understand. Given that evolution is a rather counter-intuitive idea, whether people understand evolution or not *is* a major issue, and one that may have been overlooked in the debates surrounding evolution. Throughout the book I also address some common misunderstandings about evolution, which are also summarized at the end of the book.

I should note at this point that I do not overlook the cultural, religious, worldview, and other issues implicated in the problem of the public acceptance of evolution (the term “public” is used vaguely in the present book to refer to all ordinary people). I am aware that there are powerful social factors at work, especially among fundamentalist religious believers, which may have nothing to do with conceptual issues. These people usually associate evolutionary theory with a set of liberal values that they perceive as a threat to their own conservative values. They also usually perceive evolutionary theory as a threat to important social and moral issues (see Chapter 7). However, research in the history of science and in sociology has shown that the relation between science and religion has been, and continues to be, a complex one rather than a simple dichotomy. But as many excellent treatments of the interplay between science and cultural, social, religious, and worldview factors have already been written, I have decided to rather focus on conceptual issues. Due to these, there is more to resistance to evolutionary theory than religious belief.

A note of caution: In Chapters 2 and 3 I present the findings of various studies on children’s and adults’ design teleology and psychological essentialism

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conceptions. While reading these sections, you should keep in mind two important limitations of those studies: (1) these are short-scale studies with small sample sizes; and (2) they have involved children mostly from the USA. As a result, generalizations are not easy to make, but I consider their findings as important to report. The main reason for this is that all these studies together support the conclusion that the main conceptual obstacle to understanding evolution is the “design stance”: the tendency to perceive “design” in nature and elsewhere. Even though many of us might take as self-evident what design is about, defining it is far from simple. In this book, I consider design as the property of a whole to have parts organized in such a harmonious manner so as to efficiently perform a particular function. By this definition, whatever exhibits design should also reflect the intentions of its designer: The arrangement of parts in such a way that makes a function possible should automatically reflect the intentions of the designer related to the performance of that function. In this view, all biological characteristics, that is, all recognizable features of an organism (which can exist in a variety of states and at several levels from the molecular to the organismal), are also perceived to be the outcome of intentional design.

The metaphor of design has been a popular one in evolutionary biology, and scholars have argued that Darwin explained how there can be design without a designer. Simply put, according to this view, natural selection can bring about the design that we perceive in the structure of organisms, as those organisms that exhibit the best “designs” are also those that are better at surviving and reproducing, and therefore those that pass on their characteristics to the next generation. However, personifying natural selection by thinking of it as a blind watchmaker, as Richard Dawkins has suggested, or even as a tinkerer, as François Jacob once suggested, can be misleading. Dawkins and Jacob were certainly aware, and explicit, that these are just metaphors. But metaphors can be misunderstood because people may pay attention to the part of a metaphor that makes more sense to them, and overlook its limitations. Therefore, stating that biologists can study the structure of organisms as *if* that structure exhibits some kind of design (which we would expect to see in the work of an engineer or a tinkerer), might make people pay attention to this design and its implications about the existence of a function or of a designer. But as I explain in Chapter 3, even though only artifacts exhibit design because they are intentionally created for a purpose, we tend to perceive

organisms (especially their parts) in the same way as the parts of artifacts. This is why the metaphor of design in biology had better be avoided.

The main aim of this book is to help readers understand evolution. But because evolution is a counterintuitive idea, this can only happen after readers realize why evolution is difficult to understand. I hope that after reading this book, you will not only realize which obstacles make evolution difficult to understand, but will also be guided to overcome these obstacles yourselves.

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There are always many people an author can thank for their intellectual contributions and their support in writing a book. But there is no one else that deserves to be acknowledged more in this case than Katrina Halliday, executive publisher for the life sciences at Cambridge University Press. Neither this book as you see it, nor the book series to which it belongs, would have existed without the insight and support of Katrina. The first edition of the present book, published in 2014, was very well received and was commended for its unique contribution and its readability (see excerpts from and links to the reviews at <http://kampourakis.com/understanding-evolution>). Yet, that was still an academic book. Thanks to Katrina, we now have this revised and updated, but also concise, version that I hope you will appreciate.

I am indebted to many scholars for their ideas, comments, and suggestions: John Avise, Francisco Ayala, Glenn Branch, John Hedley Brooke, David Depew, Patrick Forber, Jim Lennox, Alan Love, Kevin McCain, Sandro Minelli, Robert Nola, Ron Numbers, Greg Radick, Henk de Regt, Karl Rosengren, Michael Ruse, Mike Shank, Elliott Sober, Paul Thagard, John Wilkins, and Tobias Uller. Finally, I am grateful to Ross Nehm and Michael Reiss for useful discussions on topics related to understanding evolution over the years.

My interest in understanding evolution goes back in time. I am indebted to Vasso Zogza, my PhD advisor, who helped me understand that conceptual development research has a lot to contribute to understanding science concepts. I am also indebted to my old friend Giorgos Malamis, who guided me through my first forays into the vast literature of philosophy and history of science when I was an undergraduate student. Finally, I am grateful to Eleftherios Geitonias, founder and director of Geitonias School, and to all my

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I am also grateful to Olivia Boulton and Sam Fearnley at Cambridge University Press for their work toward the publication of this book, as well as to Gary Smith for his meticulous copy-editing. Finally, I thank Mihalis Makropoulos and Sinos Giokas, who notified me about some minor issues that they identified while working on the Greek translation of the 2014 edition.

Over the years I have extensively discussed many of the issues raised in the book with my wife, Katerina, my best friend and companion in life, who also has a background in the life sciences. Her thoughts, comments, and fierce criticism have always been valuable. Moreover, while writing I was thinking that this book should be appropriate for our children, Mirka and Giorgos, to read when they grow up. Existential questions will come up at some point and I wanted to be able to give them this book in order to read about how scientists study the natural world and what they can, and cannot, conclude about it. Thus, I have written this book with my own children and their intellectual/conceptual development in mind.

For being a source of inspiration and for making me feel sentimentally rich, I dedicate this book to my family: my wife and our children for turning an inherently purposeless life into a deeply meaningful one.