John Ellis

How Science Works: Evolution

A Student Primer

Springer

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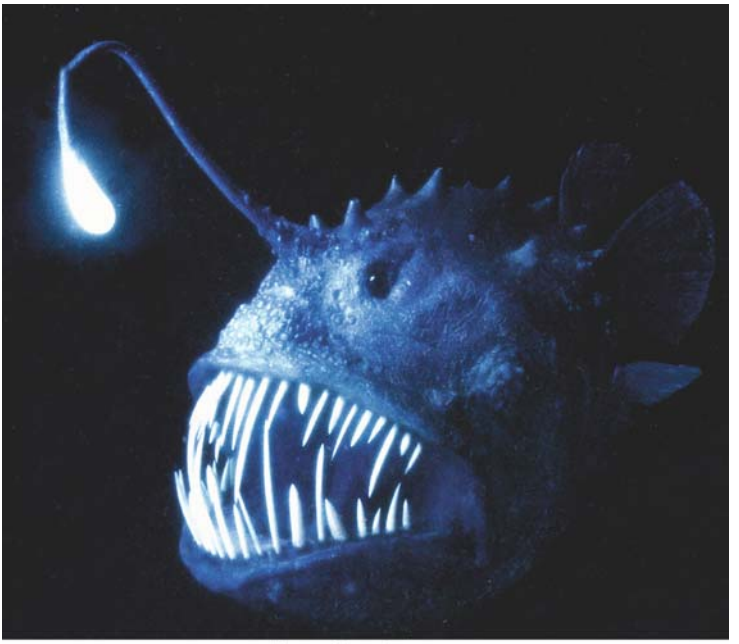

Frontispiece

The angler fish is a striking example of adaptation to life in the deep ocean. One of its dorsal spines has evolved into a moveable fleshy lure containing luminescent bacteria. The light attracts prey to within reach of the formidable jaws. The body is capable of expanding enough to swallow prey twice its size. The animal shown is a female angler fish. It is hard for the sexes to meet in the deep ocean so the smaller males bite into a female and stay attached to be fed through her blood vessels.

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R. John Ellis is an Emeritus Professor of Biological Sciences at the University of Warwick, Coventry UK, CV4 7AL. In 1983 he was elected Fellow of the Royal Society for his research on the biogenesis of chloroplasts. He received an International Gairdner Award in 2004 for fundamental discoveries in chaperone-mediated protein folding, and the Annual Medal of Cell Stress Society International in 2006 for the discovery of the chaperonins. His current interests include neurodegenerative disease caused by protein aggregation, and the effects of macromolecular crowding on cellular processes.

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Cover photograph: a land iguana on the Galapagos Islands. These animals share a herbivorous lifestyle with marine iguanas and were described by Charles Darwin during his voyage in HMS *Beagle*. Photograph courtesy of Hugh Woodland.

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All our science, measured against reality, is primitive and child-like – and yet it is the most precious thing we have

Albert Einstein

. . . and freedom of thought is best promoted by the gradual illumination of men's minds which follows from the advance of science

Charles Darwin

For Diana and Juliet

Dr. Robert Old, Department of Biological Sciences, University of Warwick.

"I would make this book required reading for all students entering University science courses".

Dr. Geoff Oxford, Department of Biology, University of York.

"Many authors, such as Dawkins, Dennett and Grayling, have discussed at length various aspects of religion and its conflict with the logic of science. In this excellent book, John Ellis ignores the moral and societal aspects of the science/religion argument and instead concentrates on exploring the way science works, and the way it doesn't, in the context of biological evolution. It clearly sets out the fundamental principles of science and how they differ from a simple deference to authority, the basis of all religions. It then examines in detail the Darwinian framework for evolution by natural selection, and the numerous lines of evidence that, independently, overwhelmingly support the theory. This is, quite simply, the best and most easily understood presentation of the arguments I have ever read".

Professor Anthony Grayling, School of Philosophy, Birkbeck College, London.

"I have just had the very enjoyable and instructive experience of reading your 'How Science Works', and think that it is exactly the kind of thing that should be sent to every school and indeed every school pupil, not to say every university student too, in the country. I hope it is! and write to applaud its clarity and organisation, and the way it grips attention from the opening words.

Professor Steve Jones, Department of Genetics University College London.

"I read your manuscript with interest, and thought it was a clear and precise introduction to evolution"

Preface

The Importance of Science

When I was growing up, I found myself, like all young people, in a world full of adults telling me stories. Stories about the nature of the world and the place of humans in it, stories about what to believe and how to behave. My problem was that there were many different stories, so how do you decide to choose between them and form your own views? I asked my father about this, and he advised me, when forming my view of the world, not to take any notice of the status of people making particular claims. It did not matter, he said, whether they were called prince or bishop or professor, or whether they wore fancy clothes like mitres or mortar boards. The only thing that mattered, he said, was the quality of the evidence in support of the claims they were making, and that I should be the judge of that quality. By quality, he meant how robust was the evidence? Was it just an opinion derived from what other people said, or was it based solidly on empirical observations anyone could make? In other words, how scientific was the evidence?

This book is based on my father's advice to seek out the best-quality, empirical evidence you can find, and stick to what it implies until better evidence comes along. It is the *quality* of the evidence that you need to learn how to evaluate. In this book I discuss the criteria you should bear in mind when evaluating the evidence for any claim, in the hope that this will help you to develop an independent, critical way of thinking. Reduced to the simplest terms, my advice to you when confronted by people making claims about any subject is not to accept their claims at face value, but to ask "How do you know that?" and rigorously examine the quality of the replies they give.

I decided to write this book after I was asked by Hugh Woodland in 2006 to contribute to a new course in evolution to undergraduates studying biology at the University of Warwick. This request came as a surprise because my research career, before my retirement in 1996, had been in protein biochemistry and I had not taught evolution before. The motivation for devising this new course was partly the feeling that we did not talk about evolution enough at Warwick, given its central importance for all aspects of biology, and partly to combat the resurgence of creationist views that was claimed to be happening in Britain. The latter claim surprised me because

evolution had been established as a fact in the 19th century, so I consulted Michael Reiss from the Institute of Education, then on temporary secondment to the Royal Society as its Director of Science Education.

Michael Reiss confirmed to me that increasing numbers of students were entering school and universities who do not accept evolution because their parents do not. He further explained that the response of teachers to such students tended to take one of two courses. They either disparaged and ridiculed the views of these students or they ducked the whole issue, and did not discuss either evolution or creationism. Michael Reiss took the view that both responses are counter-productive, and that a better response to this situation would be to use it as an opportunity to explain how science works and differs from other ways of explaining the world, and hence why creationism is not science.

I began to read about evolution and the issues surrounding it today, and the document that impressed me the most was the online record of the court case held in Dover, York County, Pennsylvania, in 2005. This record can be read at: http://www.pamd.uscourts.gov/kitzmiller/decision.htm. In this case, a group of eleven parents sued their local school Board of Education for requiring that a statement referring to intelligent design as an alternative to evolution must be read to students attending biology lessons, implying that intelligent design is a scientific theory. Intelligent design was defined during this case as meaning that "various forms of life began abruptly through an intelligent agency, with their distinctive features already intact - fish with fins and scales, birds with feathers, beaks and wings etc". The theory of evolution, in contrast, states that all forms of life are related to one another and change with time.

The judge was asked to decide whether intelligent design is a scientific view or a religious view, because the First Amendment of the Constitution of the United States states that "Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof; or abridging the freedom of speech, or of the press". This Amendent thus forbids the teaching of religion in state-funded schools in order to preserve both the freedom of religion and the separation of religion from the state. The judge had to decide how science differs from religion, and to this end several philosophers who had studied this matter gave evidence. The record of the testimony that led the judge to rule that intelligent design is a religious view, and not part of science, is available online, and I found it to be a valuable source of information about the views of philosophers regarding the distinctions between science and religion. References to articles by two of these philosophers, Barbara Forrest and Robert Pennock, are given in the Further Reading list at the end of Chapter 1.

There was a second experience that persuaded me to teach in what, for me, was a new area. I watched an interview by Jeremy Paxman on the BBC TV programme *Newsnight* with the late evolutionary biologist John Maynard Smith. Paxman started the interview by asking Smith "Evolution is just a theory, isn't it?" Smith replied that the evidence for evolution is as good as the evidence for the existence of atoms, but that, on the other hand, he could not rule out the possibility that his whole knowledge of the world had been implanted in his brain ten seconds ago by a

capricious supernatural agent. This exchange made me realise that even a person as educated and intelligent as Jeremy Paxman apparently did not realise what the word "theory" means in science or that all scientific knowledge is provisional and subject to change.

My decision to write this book was confirmed by an article that appeared in *The Guardian* newspaper on November 20th, 2008, written by Jim Al-Khalili, a professor of physics and the public engagement in science at the University of Surrey. He wrote

> I do feel strongly that those scientists who have a voice must be doing more than simply popularising their field in order to attract the next generation into science. Yes, this is vital: but it is also vital that we help defend our rational secular society against the rising tide of irrationalism and ignorance. Science communicators, for want of a better term, have a role to play in explaining not just the scientific facts but how science itself works: that it is not just 'another way of explaining the world', and that without it we would still be living in the dark ages.

I have chosen evolution as the example for explaining how science works because it graphically illustrates the issues I wish to address, and because evolution is under increasing attack in some educational establishments. Biologists regard evolution as both a theory and a fact, but evolution is more than just another scientific theory because it challenges those views that suggest humans are basically different from other animals and so can escape the laws of nature. It is this aspect of evolution that makes it so unattractive to many people. But rejecting evolution or any other branch of science means that we reject the best means we have found so far to understand ourselves and our place in the world. Evolution is the greatest story ever told.

You may find some elements of this book controversial, so let me say right at the start that it is not my intention to tell you what to think. My intention is to help you to learn *how* to think, by discussing the sorts of consideration you should bear in mind when formulating your own views about the nature of the world, especially about how scientists study the world. The term "world" in this book means everything that we experience.

Coventry, UK John Ellis

Acknowledgements

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