UNDERSTANDING
EVOLUTION

KOSTAS KAMPOURAKIS

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KOSTAS KAMPOURAKIS
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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

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

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

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.

Acknowledgments

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 Geitonas, founder and director of Geitonas School, and to all my

former colleagues there who supported my research during the 12 years that I worked there as a biology teacher.

I am also grateful to Olivia Boult 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.

1 The Public Acceptance of Evolution

Evolution in the Polls

What is evolution? The term might refer either to the *fact* that species have changed over the course of eons, or to the *process* by which this change has taken place, resulting in their exquisite adaptations and their outstandingly common features. All organisms are related to one another because they have descended from a common ancestor through natural processes that have produced new life forms from preexisting ones. It is important to note that evolution has been taking place on Earth for billions of years. Consequently, although it is still taking place now, much of the information about it comes from the past. Evolutionary scientists do not have a direct view of the past, but they can infer past events from what they currently observe. Overall, there is ample evidence for evolution in fossils, anatomy, biogeography, and DNA.

However, the idea of evolution in general and of human evolution in particular is usually misrepresented in the public sphere, with illustrations such as the one in Figure 1.1. There are two main problems with this representation of human evolution. First, it portrays evolution as a linear process in which each one of the species changes into another one. However, evolution is more accurately represented as a branching process, not a linear one. Second, this representation shows humans evolving from apes that exist today. This is misleading too, because a species cannot evolve from other contemporary species. What is actually happening is that humans and apes share common ancestors, from which they have evolved independently, like branches starting from a common shoot. But before explaining evolution in detail, it is interesting to consider its public image.

that in highly religious countries the acceptance of evolution is lower than it is in more secular countries. Thus, one might be tempted to infer that the more religious a country is, the less accepted evolution will be. However, when one looks into the details, there is not a simple evolution/religion dichotomy, and what emerges is a more complicated picture. In this chapter, I focus mostly on conceptual and inferential issues, leaving the methodological issues aside, because I am interested in the conceptual content of the questions and in how the emerging results might be (mis)interpreted.

Some articles presenting results of evolution-focused polls around the world have attracted considerable attention. For instance, a 2006 article published in the prestigious journal *Science* compared attitudes in various countries to the statement that "Human beings, as we know them, developed from earlier species of animals." Participants were asked whether the statement was true or false, whether they were not sure or did not know. It was found that about 25 percent of participants from Turkey and about 40 percent of participants from the USA considered the foregoing statement as true, whereas this was the case for more than 80 percent of participants from Iceland, Denmark, Sweden, and France. Another article, published a couple of years later – again in *Science* – reported on the findings of a study in predominantly Muslim countries, asking participants the following question: "Do you agree or disagree with Darwin's theory of evolution?" Not many people agreed that Darwin's theory is probably or almost certainly true: 16 percent in Indonesia, 14 percent in Pakistan, 8 percent in Egypt, 11 percent in Malaysia, 22 percent in Turkey, and 37 percent in Kazakhstan. Such findings seem to show a clear pattern: People in more religious countries are less likely to accept evolution than people in more secular countries, as well as that people in predominantly Christian countries are more likely to accept evolution than people in predominantly Muslim countries. However, if one looks at the details of these polls, there is more than that, as I show in the subsequent sections.

Evolution Polls in Europe

During January–February 2005, data from 32 countries were collected, through personal interviews, by the European Commission. The findings were published in the Eurobarometer survey 63.1 in June 2005 (this is where much of the data for the 2006 *Science* article previously discussed came from).

The study involved participants from the 25 (at that time) member states of the European Union, as well as from Bulgaria, Romania, Croatia, Turkey, Iceland, Norway, and Switzerland. Two reports were released. The first one was titled *Special Eurobarometer 224: Europeans, Science and Technology*, and the other was titled *Special Eurobarometer 225: Social Values, Science and Technology*. One of the questions asked in the survey concerned the statement: "Human beings, as we know them, developed from earlier species of animals." Participants were given the choices "true," "false," or "don't know." The findings are presented in Figure 1.2.

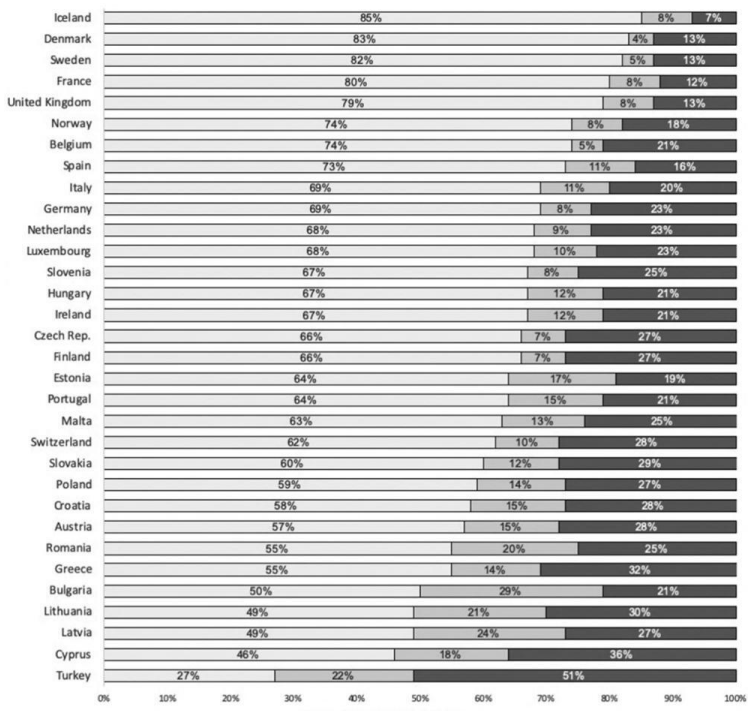

Figure 1.2 Acceptance of the idea "Human beings, as we know them, developed from earlier species of animals" in European countries and Turkey.

The first noteworthy issue is the content of the survey statement itself. Strictly speaking, the statement is incorrect because no species can "develop" from an earlier species. The term "development" is currently used in the life sciences to refer to individual life cycles and within-generation time spans. It is rather "evolution" that refers to populations and time spans across generations. Therefore, the statement should instead have been written as "Human beings, as we know them, *evolved* from earlier species of animals." It is unclear whether replacing the verb "evolve" with the verb "develop" was done accidentally, or intentionally in order to refrain from using an evolution-related word. One might indeed argue that if using an e-word is a sensitive issue, one had better refrain from using it and replace it with less sensitive words. However, such a choice raises important conceptual issues. If you think about this, the word "development" implies a more goal-directed process than "evolution." Stating that humans have developed from earlier species might be perceived to imply that this was an inevitable outcome; however, human evolution was far from inevitable.

Conceptual issues notwithstanding, what else do we see in Figure 1.2? There are multiple ways to look at the results. One is that the majority of participants in all European countries accepts the idea of humans originating from animal predecessors, an idea rejected by half of the participants in Turkey. This sounds like good news for Europe. However, if you look closely at the results, you will also see that between one in five and one in four people in most European countries reject this idea. If you add to these the number of people who do not know what to think, overall about one in three Europeans does not accept the idea of human origins from animal predecessors. One might still be pleased with these results though, especially given that in the same survey about one in three participants in the 25 EU countries agreed with the statement that "The Sun goes around the Earth" and that about one in five people agreed with the statement that "The earliest humans lived at the same time as the dinosaurs." In other words, there are fundamental issues related to science literacy that do not have to do with the idea of evolution only. Some people may just be ignorant about science in general, and not antievolutionists.

Nevertheless, a usual concern whenever there are people who seem not to accept the idea of evolution is that their religious worldviews may be responsible for this. Another question asked in the survey was the following: "Which of these statements comes closest to your beliefs?" Participants could choose

among the following statements: "I believe there is a God"; "I believe there is some sort of spirit or life force"; "I don't believe there is any sort of spirit, God or life force"; "I don't know." As is evident in Figure 1.3, there is variation in the belief in the existence of God in the various countries. However, some kind of spirituality is also quite widespread, and as a result less than one in three participants in all countries expressed their disbelief in the existence of God or some spiritual entity.

A question then comes up naturally: Is there a connection between the belief in the existence of God and the low acceptance of evolution? Figure 1.4 presents together the results already presented in Figures 1.2 and 1.3 about the number of people who believe in the existence of God and the number of people who considered the statement that "Human beings, as we know them, developed from earlier species of animals" as being false.

Two important inferences can be made from Figure 1.4. The first one is that not all people who believe in the existence of God also consider the idea of humans originating from animal predecessors as false. What is even more interesting, though, is that, with the exception of Turkey, the number of participants rejecting the idea of humans originating from animal predecessors is 20–30 percent in most countries, both in the more "religious" and in the less "religious" ones. The results were quite different in Turkey, which is also the only predominantly Muslim country. These findings support the conclusion that Christianity, which is the major religion in Europe, does not necessarily relate to opposition to the idea of evolution. However, the findings from polls in the USA provide a very different picture.

Evolution Polls in the USA

For a period of 37 years, between 1982 and 2019, Gallup has been conducting surveys in the USA, asking participants the following question: "Which of the following statements comes closest to your views on the origin and development of human beings?" Participants could choose one among the following options:

- Human beings have developed over millions of years from less advanced forms of life, but God guided this process.
- Human beings have developed over millions of years from less advanced forms of life, but God had no part in this process.

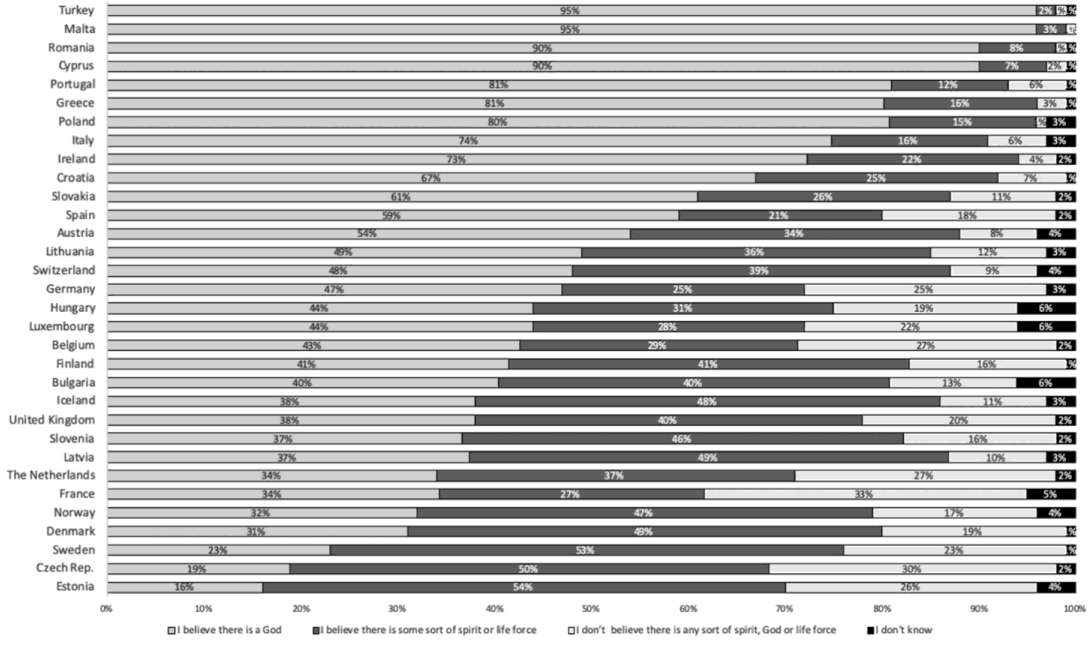

Figure 1.3 Belief in the existence of God or some sort of spirit or life force in European countries and Turkey.

"evolution"? Perhaps, but this remains to be seen in subsequent polls. For now, more than 70 percent of people in the USA believe either that God created us humans or that God has guided our evolution (Figure 1.5).

One might wonder why about three out of four people in one of the most advanced countries in science and technology in the world think that God either created humans or has driven our evolution. There are several facts to consider. For instance, the conclusion from the 2017 survey is that people with higher education are more likely to accept the evolutionary explanation for human origins and less likely to support "creationism." In particular, among people with postgraduate education, 21 percent accepted "creationism" and 31 percent accepted "evolution," whereas this was the case for 48 percent and 12 percent, respectively, of people with high-school education or less. However, the Gallup report noted that "even among adults with a college degree or postgraduate education, more believe God had a role in evolution than say evolution occurred without God." Many would claim that higher levels of education might make one less likely to accept supernatural explanations and more likely to accept natural ones. However, there may be other reasons that about three out of four people in the USA currently seem to prefer responses that implicate God in human origins.

Let me explain. In addition to the Gallup poll, the Pew Research Center has also conducted surveys in the USA about evolution. Let us compare the Gallup and Pew surveys conducted in the USA between 2008 and 2014. I have arbitrarily put together surveys conducted in different years, but my aim is not to compare those but simply to show trends across time. Table 1.1 presents the exact wording of the choices made available to participants in the Pew and Gallup surveys. The findings of these surveys are presented in Figure 1.6.

Even though both the Gallup and Pew polls practically provided participants with the same three options ("evolution," "theistic evolution," and "creationism"), the results in Figure 1.6 indicate two quite different situations. Assuming that all surveys involved a representative sample of the US population, one should not expect significant differences in participants' responses to the two polls. However, this is not the case. On the one hand, twice as many participants selected "evolution" in the Pew polls compared to the Gallup polls. On the other hand, more participants selected "theistic evolution" and "creationism" in the Gallup poll compared to the Pew poll. But how is this

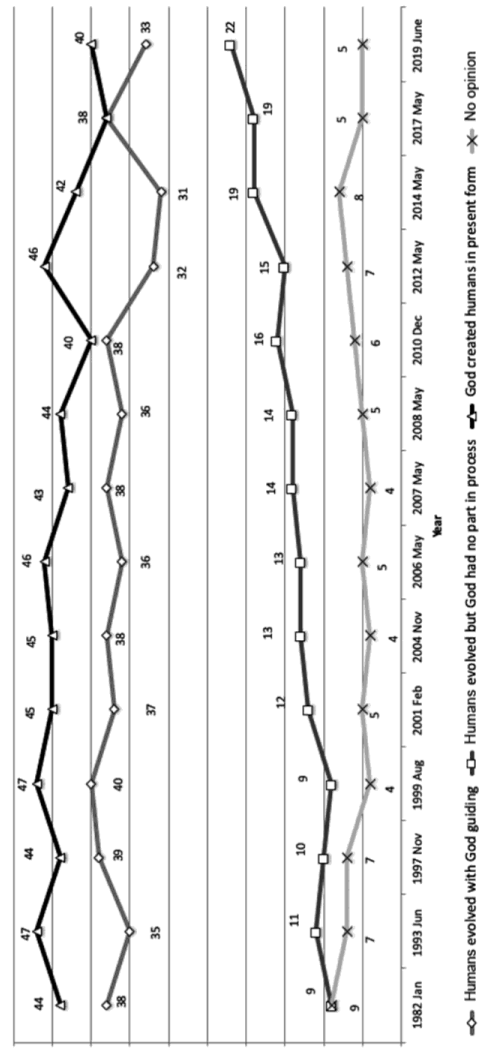

Figure 1.5 Public acceptance of evolution in the USA during a period of 37 years.

Type of question	Gallup	Pew
"Evolution"	Human beings have developed over millions of years from less advanced forms of life, but God had no part in this process.	Humans and other living things have evolved due to natural processes such as natural selection.
"Theistic evolution"	Human beings have developed over millions of years from less advanced forms of life, but God guided this process.	A supreme being guided the evolution of living things for the purpose of creating humans and other life in the form it exists today.
"Creationism"	God created human beings pretty much in their present form at one time within the last 10,000 years or so.	Humans and other living things have existed in their present form since the beginning of time.

Table 1.1 The choices given to participants in the question related to evolution in the Gallup and Pew polls until 2014

possible? If the differences are not due to sample sizes or a biased sampling of participants, what could then account for them? There are actually two important issues, one conceptual and the other methodological.

The conceptual issue relates to the content of the phrases. Look carefully at Table 1.1 and compare the phrases therein. Do you see any difference? Well, the word "God" appears in all Gallup phrases but in none of the Pew ones; the term "supreme being" only appears in one of those. Demonstrating an effect of such differences in wording on participants' responses would require an empirical study in which some participants from the same samples and responding under the same conditions would be given the Gallup phrases and others would be given the Pew phrases. Until this is done, I cannot establish that the differences in phrasing have an effect. However, the

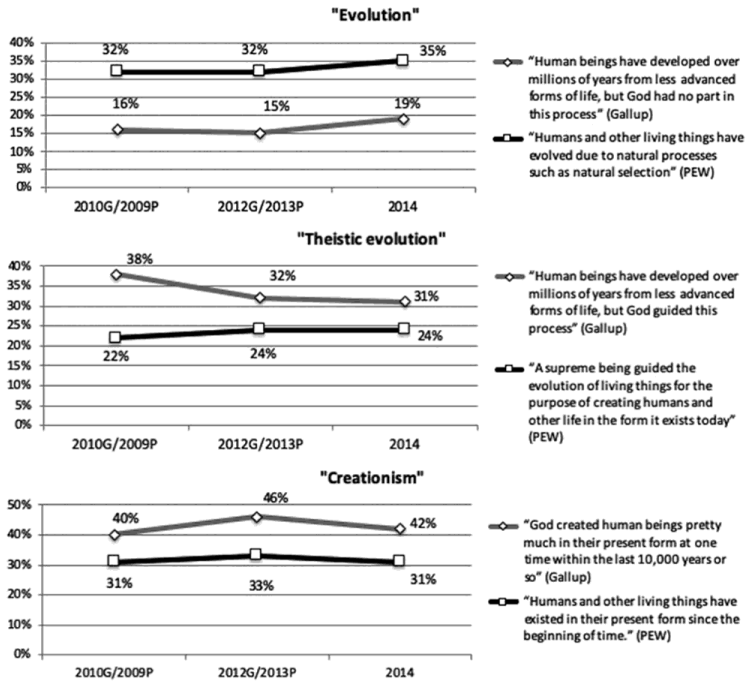

Figure 1.6 The percentages of participants of the Gallup and Pew surveys accepting "evolution," "theistic evolution," and "creationism."

different results in the Gallup and Pew polls make plausible the assumption that this could be the case, and this is something worth investigating.

The methodological issue stems from the fact that, whereas all three statements were given to Gallup participants at the same time, this was not the case for the Pew participants. There, in contrast, participants were first asked which of the following phrases comes closer to their own view: "Humans and other living things have evolved over time" or "Humans and other living things have existed in their present form since the beginning of time." Then, those who chose the first phrase were also asked if they thought that "Humans

and other living things have evolved due to natural processes such as natural selection" or "A supreme being guided the evolution of living things for the purpose of creating humans and other life in the form it exists today." But why might receiving all three options together or in two consecutive steps have an effect on participants' responses?

The researchers at the Pew Research Center have actually tested this in a recent survey (April 23 to May 6, 2018). Participants were randomly assigned to one of two conditions: Half of them were asked a single question about evolution and were given three options: "Humans have evolved over time due to processes such as natural selection; God or a higher power had no role in this process"; "Humans have evolved over time due to processes that were guided or allowed by God or a higher power"; or "Humans have existed in their present form since the beginning of time." The other half of the participants were asked about evolution in a two-step process: They were first asked if they thought that "Humans have evolved over time" or if "Humans have existed in their present form since the beginning of time." Then, those who agreed with the idea of evolution were asked a second question, whether they thought that "Humans have evolved over time due to processes such as natural selection; God or a higher power had no role in this process," or that "Humans have evolved over time due to processes that were guided or allowed by God or a higher power."

The results were very interesting. Among those asked the questions in two steps, 40 percent chose "evolution," 27 percent chose "theistic evolution," and 31 percent chose "creationism"; in contrast, among the participants who were given all questions at the same time, only 18 percent chose "creationism," whereas 33 percent chose "evolution" and 48 percent chose "theistic evolution." The Pew researchers thus concluded that testing multiple ways of asking about evolution is necessary and important. They explained the higher acceptance of evolution in the one-step approach as being due to the fact that respondents were not put in the dilemma of creation or evolution, but could choose among all three options right from the start.

The one-step approach is actually the one that Gallup had been using over the years. It is then interesting to compare the most recent Gallup (June 3–16, 2019) and Pew (April 23 to May 6, 2018) polls (Table 1.2) using this approach.

respondents what their beliefs about God are, but the choices given are actually about whether participants believe in God. In contrast, Question 3 is clearly asking people what their beliefs about evolution or creationism are, as people are asked to agree with one of these views or choose the option of being unsure. In short, Question 1 asks people whether they *believe in* God, whereas Question 3 asks them what they *believe about* the origin of humans. But is this an important difference? Yes, it is. Let me use an example to explain. On the one hand, a child might have *beliefs about* Santa Claus, such as that he is nice, generous, has a long beard, and wears red clothes without necessarily *believing in* Santa Claus – that is, without believing that Santa Claus really exists. On the other hand, a child might *believe in* the existence of Santa Claus without holding any specific *beliefs about* him. The case is similar for evolutionary theory. For instance, a biologist might have many *beliefs about* evolutionary theory – that is, understand it and consider it as a useful heuristic for making predictions and conducting experiments. However, that person might not actually *believe in* evolutionary theory – that is, esteeming and valuing it – because it conflicts with her deeply held religious convictions. Conversely, a student might *believe in* evolution – that is, accept that it is true simply because she has heard a prominent scientist saying it is true – without understanding it and thus holding *beliefs about* it.

A second problem is conceptual. Question 3 states that "the origin of man came from evolving from other species such as apes" and that "human beings were in fact created over a long period of time of evolution growing into fully formed human beings they are today from lower species such as apes." The problem here is that these statements might be perceived to imply that humans evolved from the apes that exist today. However, this is not what evolutionary theory suggests; rather, what is suggested is that humans have a common ancestor with these apes, which was probably ape-like, but still different from the apes that exist today. Now, you might wonder, is this a big difference? Ape or ape-like, it is still an ape, isn't it? Well, I think there is. To put it simply: Is it the same to say that you are descended from your first cousin, and that you and your first cousin have a common grandfather and grandmother? The former is impossible, the second is correct. Whether or not the cousin and the grandparents are apes is secondary.

Let us now consider the findings of the Ipsos 2011 study and the respective inferential issues. Figure 1.7 presents how many people in each country

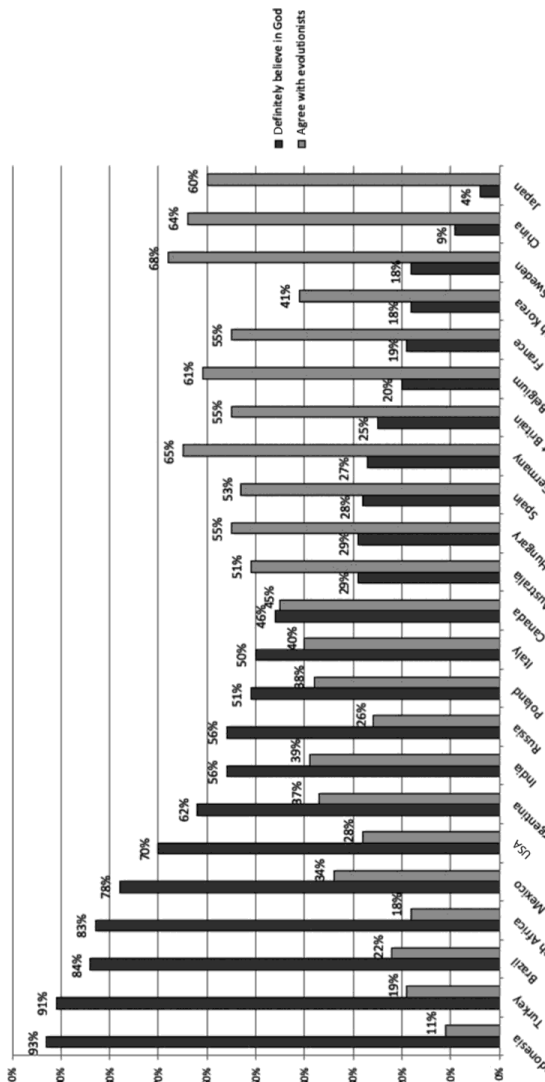

Figure 1.7 The usual image found in polls is that there is a negative correlation between belief in God and acceptance of evolution.