1 Scientists and Their Hecklers

1.1 DARWIN PRESENTS HIS THEORY

Charles Darwin presented his theory of evolution in his book *On the Origin of Species*, published in 1859. In so doing, he transformed biology from a scientific backwater to a fully professional science. Prior to Darwin, biology was little more than the art of catching an animal, killing it, cutting it open, and then writing detailed descriptions of what you saw. Alternatively, some biologists concerned themselves with classifying organisms according to whatever arbitrary characteristics had their attention that week. Valuable work, no doubt, but hardly a science. *Real* science involved abstract theorizing, mathematical modeling, and predictive power to several places past the decimal point. Or so went the stereotype, at any rate.

That all changed with Darwin. By marshaling evidence from classification, biogeography, embryology, and comparative anatomy, he established, to the satisfaction of most scientists, that organisms shared a far greater degree of relatedness than had previously been appreciated. He also provided a possible mechanism to explain how populations of organisms gradually became better adapted to their environments – the process of natural selection. He anticipated, and provided cogent replies to, numerous theoretical objections to his ideas. Biology now had a bona fide theory from which to work, one which could be tested against data and which suggested fruitful directions for further research.

The ensuing 162 years (keeping in mind that I am writing this in early 2021) led to one success after another for evolution. Realizing that a thorough understanding of heredity was necessary for assessing the theory, scientists undertook a program of research that

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eventually led to the modern science of genetics. In the 1920s and 1930s, mathematical models were developed to help understand gene flow and other evolutionary processes, thereby showing that natural selection was not just possible but also plausible as a mechanism for large-scale evolution. In the 1940s, developments in paleontology, genetics, physiology, zoology, and botany were united into the so-called modern synthesis, showing that the data from every branch of the life sciences seemed to converge on evolution, with natural selection as its primary mechanism. Subsequent developments in molecular biology, and technological developments that made possible new research directions in genetics, provided lines of evidence for evolution undreamed of by Darwin or his immediate successors. The more that was learned about biology, the more evolution came to seem obvious.

Evolutionary thinking soon led to progress in other branches of science. Ecologists realized that evolution was essential to understanding the temporal and spatial distribution of species. Medical researchers came to use evolutionary thinking to understand the process of antibiotic resistance in bacteria, to investigate the origins of genetic disorders, and to devise effective treatments against a host of ailments. Computer scientists used genetic algorithms to solve problems in engineering, meaning they explored large spaces of possibilities by mimicking the process of evolution by natural selection.

Today, evolutionary theory retains pride of place in biological thinking. Modern evolutionary biology includes a large role for Darwin's main ideas, in the sense that the common descent of all modern organisms is considered to be beyond dispute and natural selection is still considered to be an especially important mechanism of evolution. But the subject has also been enriched by many ideas that go well beyond anything Darwin considered. Research into evolution seems to generate novel ideas faster than they can be assessed and assimilated. The field is marked by ferment over details coupled with confidence in the fundamentals.

However, there are today, and always have been, others who are unimpressed by this long track record of success. For as long as biologists have been studying the processes of biological evolution, there have been critics heckling them from the sidelines. The critics claim that evolution is only weakly supported by the available evidence, to the extent that it is supported at all. They claim that evolution has represented a tragic wrong turn in the history of ideas, and that it must be replaced, or at least heavily supplemented, with the idea that an intelligent designer is in some way manipulating the process. In their more florid moments, they claim that evolution is a flatly ridiculous theory, that nothing more than common sense and a high school education is sufficient to see this, and that scientists are blind to this reality because of morbid anti-religious bias.

They make many arguments in support of this view. Some of those arguments rely heavily on mathematics. This book explains why those mathematical arguments are wrong.

1.2 WHO ARE THE HECKLERS?

In the United States in the twenty-first century, there are two main schools of anti-evolutionist thought: Young-Earth Creationism (YEC) and Intelligent Design (ID). You can certainly identify other schools and draw subtle distinctions among their various religious commitments, but the fact remains that YEC and ID all but monopolize the discourse.

YEC holds that Earth was created no more than 10,000 years ago. (Relative to the more standard scientific estimate of roughly four and a half billion years, this constitutes a young Earth.) YEC also claims that modern species were created in essentially their present form. Moreover, it claims that species can be grouped together into distinct "kinds," and that while small amounts of evolutionary change within a kind are possible, more significant change between kinds is not. The basic facts of geology and paleontology, they go on to argue, are best explained by reference to a global deluge a few 1,000 years ago. Critically, they claim that while these ideas are certainly

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consonant with what is presented in the early chapters of the biblical book of Genesis, they are nonetheless also supported by our best current understanding of the scientific data.

ID is far more modest. It claims only that natural selection is insufficient to explain certain aspects of modern organisms and that therefore modern evolutionary theory is fundamentally flawed. Proponents of ID also claim they can prove that even in principle no naturalistic mechanism can fully explain the interlocking complexity of modern organisms and that a satisfactory explanation can only be found by appealing to some sort of action on the part of an unspecified intelligent designer. They take no stand on the age of Earth, though most of ID's leading representatives accept that Earth is older than the biblical chronologies suggest. They also have nothing much to say about the identity, abilities, and motivations of the designer, nor do they tell us what the designer actually did. There is really little more to their scientific theorizing than the assertion that an intelligent designer of unspecified motives and abilities did something at some point in natural history.

There are cultural differences between the two groups. Proponents of YEC generally endorse the anti-evolution arguments presented by proponents of ID, but they also find that ID does little to promote religious evangelism. They argue that vague references to an unspecified designer do nothing to win souls for Christ and that this is a serious shortcoming of ID. While they are adamant that their views can be defended entirely on scientific grounds, they also make no secret of their religious motivations.

On the other side, proponents of ID are mostly contemptuous of YEC. They find that YEC literature is generally of such low quality that it brings disrepute to the whole project of anti-evolutionism. The leading proponents of ID are better credentialed than their counterparts in YEC, and they express themselves with far more scientific sophistication than most proponents of YEC can muster.

These differences are real and important. Nonetheless, the proper analogy for the relationship of YEC to ID is that of different

dialects of the same language. Both are religiously motivated attacks on evolution, and both camps see the evolution/creation dispute as one front in a larger culture war. While ID proponents are more skillful at deploying scientific jargon, the arguments presented by the two camps are essentially the same.

This leads us to the most important similarity of them all: scientists are all but unanimous in finding both ID and YEC arguments to be entirely fallacious. In most cases, scientists do not even find the arguments interesting or thought provoking. They just find them to be wrong for crass and obvious reasons.

While ID and YEC both have considerable cultural cachet, we will be spending far more time discussing the arguments of the former than the latter. Our interest in this book is solely in the merits of their mathematical arguments as applied to evolution, so we will not give any further consideration to the cultural milieu in which these arguments are presented. The arguments stand or fall on their own merits, independent of any unsavory motivations underlying them.

That acknowledged, it is pointless to deny that certain overly-conservative interpretations of religion are at the foundation of modern anti-evolutionism. And since we are going to conclude that the anti-evolutionist's mathematical arguments are very poor, it is reasonable to keep their unscientific motivations in mind as we consider them.

1.3 BAD MATH CAN BE RHETORICALLY EFFECTIVE

My introduction to anti-evolutionism came a little over 20 years ago when I was a graduate student studying mathematics at Dartmouth College. While I was there, the student newspaper published an opinion piece by a creationist student. In part because I was looking for a distraction from my thesis research, which was not going well at that time, I used it as an opportunity to learn more about the evolution/creation dispute.

Initially, I did not have a strong opinion on this issue one way or the other. I have never been especially religious, and I certainly

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was not inclined to treat the book of Genesis as a literal, historical account. However, I was open to the possibility that biologists, precisely because they were so often attacked by religious demagogues, had overreacted by exaggerating the strength of their case.

Figuring that I at least knew the basics of evolutionary biology, I started by working my way through a stack of creationist books and articles. What I found was a bewildering array of arguments drawn from numerous branches of science. Creationist authors discussed fossils in one chapter, then genetics in the next, then anatomy, then physics, and on and on. Never having made a serious study of these fields up to that time, I often did not have cogent replies at my fingertips. Still, I was skeptical of the sheer magnitude of their accusations and the extreme simplicity of their arguments. People study for years to become experts in any one of those disciplines, but here was a creationist author with no particular credentials telling me that the professionals in almost every branch of science were just foolish and incompetent. I was expected to believe that the professionals had simply overlooked things that would have been obvious to a bright high school student. That seemed unlikely.

The near-unanimous scientific consensus in support of evolution has held up for well over a century. Now, it is certainly true that entrenched ideas can become so ossified and unquestioned that rival theories find it difficult to get a fair hearing. Just as with every other human enterprise, professional science sometimes confronts its practitioners with social or political pressure to conform to the dominant paradigm. For these reasons, I would never consider the mere fact of consensus to be proof that the theory is correct.

However, I do think a long-standing consensus in support of a theory counts for *something*. To me it suggests that while the theory might be wrong, it is not going to turn out to be crazy. We can always imagine some future discovery that forces us to rethink fundamental ideas, but it is hard to imagine that a well-supported theory will suddenly collapse because a talented amateur notices a conceptual

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error at the heart of the entire enterprise. If you possess any skeptical impulses at all, then claims of that sort really ought to trigger them.

This skepticism was justified for me by the abuse of mathematics in creationist discourse. Their arguments frequently used probability theory, and they often carried out specific calculations meant to convince me that evolution had been refuted. (We will discuss arguments of this sort in Section 5.5.) The fine points of paleontology and biology might have been beyond me at that time, but I certainly knew a bad probability argument when I saw one. To be clear, I am not speaking now of subtle errors. I am not saying they raised interesting questions, but had overlooked some difficult, technical point. I am talking instead of errors that betrayed an utter incomprehension of the subject.

I reasoned that if creationists were *that* wrong when discussing topics with which I was very familiar, what confidence could I have that their arguments in other branches of science were any more cogent? As I delved into the responses to creationists provided by scientists and philosophers, and more importantly as I had the chance to discuss these questions in person with the relevant professionals, it became clear that I was right to be very skeptical.

I finished graduate school in 2000 and accepted a postdoctoral position (academic speak for an internship) at Kansas State University. A significant portion of my job involved issues in public education, specifically related to the training of mathematics teachers. At that time, Kansas was the focus of national controversy because a politically conservative state school board had voted to eliminate all mention of evolution in the state's standards for science teachers. This put the evolution/creation issue back on my radar, and when I subsequently learned of a large creationist conference taking place near to my home, I decided to attend.

Over the next 8 years or so, both in Kansas and later when I moved to the western part of Virginia, I attended a great many gatherings related to anti-evolutionism. Some were large conferences

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like the one I attended in Kansas, and others were small, one-day gatherings in local churches. Some of these meetings were devoted to YEC, while others were about ID. Regardless, mathematical arguments were prominent at both. The reactions of the conference goers led me to the conclusion in the title of this section.

For example, at one major creationist conference, I was in the audience for a keynote talk devoted to the branch of mathematics known as "information theory." There were roughly two thousand people in the audience. The speaker went on for close to an hour about how insights from this field could be used to refute evolution and to support creationism. When the talk ended, the audience erupted into a standing ovation. The host of the conference session said, in awe-struck tones, that this was one of the most powerful apologetic arguments he had ever heard. My reaction was considerably more critical. Apparently, where I had seen an absurd caricature of a major branch of mathematics, the audience had seen mathematical support for their religious convictions. (We will look at arguments of this sort in Chapter 6.)

Another time, at a conference promoting ID, I was in a small breakout session of about twenty people. The speaker presented a probability calculation of the sort to which I referred a few paragraphs ago. The result of the calculation was a very small number, and the speaker breathlessly informed the audience that this showed that evolution required us to believe that something extremely improbable, if not flatly impossible, had occurred. At the end of the talk, an audience member said, with a facial expression that suggested the utmost seriousness, "When scientists are confronted with a number that small," and here he paused for dramatic effect, "what else can they do but just stare at it helplessly?" Many of the other audience members offered vigorous nods in response. When it was my turn to speak, I suggested that an alternative to staring helplessly was to question the assumptions underlying the calculation, and I pointed to several ways that those assumptions were hopelessly unrealistic. The audience was not amused.

I could provide many further anecdotes of this sort. Mathematics is unique in its ability to bamboozle a lay audience, making it well suited to the cynical machinations of anti-evolutionist speakers and authors. As a mathematician, I take some offense at that. In large measure, that is why I decided to write this book.

1.4 DOES EVOLUTION HAVE A MATH PROBLEM?

Though Darwin was largely successful at persuading scientists of the fact of common descent, he also faced formidable critics. In the later decades of the nineteenth century, it was still possible to be a scientifically informed skeptic of evolution, especially of the idea that natural selection was a plausible mechanism for large-scale change. First-rate scientists like Louis Agassiz and St. George Mivart placed themselves in opposition to Darwin's ideas, and their arguments could hardly be dismissed as the ignorant ravings of religious demagogues. For his part, Darwin offered forceful replies to the critics, and the debate petered out to something of a draw. Darwin presented a strong case for common descent and a decent plausibility argument for natural selection, but there were numerous gaps that could only be filled by further research.

By the early twentieth century, the debate landscape had changed in at least two ways. Scientifically, the case for evolution only became stronger. Paleontologists found numerous transitional fossils that made it easier to accept the possibility of large-scale transmutation in the course of natural history. Advances in the study of heredity showed that the proposed rivals of natural selection were not workable, and mathematical modeling established that selection could be a more powerful force than had been previously understood. These and other research findings were all consistent with the main ideas of evolutionary theory, and this made it harder to be an informed critic.

Meanwhile, evolution had made the jump from an esoteric theory of interest primarily to professional scientists to an idea that pervaded the culture more generally. The theory made its way into

public school curricula, and religious fundamentalists saw this as nothing less than an attack on the souls of their children.

These two shifts – the growing strength of the scientific case for evolution coupled with its increased cultural presence – led to a dramatic decline in the quality of anti-evolutionist discourse. Where once the critics could boast of giants like Agassiz and Mivart, now their most visible advocates were amateur scientists like George McCready Price and politicians like William Jennings Bryan. Cogent scientific arguments against evolution became more difficult to find, but imprecations against godless scientists and creeping materialism were commonplace. This sort of advocacy came to a head in the events of the Scopes "monkey" trial in Tennessee in 1925. Culturally, the legacy of the trial was that anti-evolutionism became all but synonymous with an especially obscurantist form of religion.

As representative of the poor state of their argumentation, let us consider a small book by William A. Williams called, *The Evolution of Man Scientifically Disproved, in* 50 *Arguments*, the final version of which was published in 1928. Williams was a Presbyterian clergyman, and he placed mathematical arguments front and center in his argumentation. He writes,

> Every theory to which mathematics can be applied will be proved or disproved by this acid test. Figures will not lie, and mathematics will not lie even at the demand of liars. Their testimony is as clear as the mind of God. … The evolution theory, especially as applied to man, likewise is disproved by mathematics. The proof is overwhelming and decisive. Thus God makes the noble science of mathematics bear testimony in favor of the true theories and against the false theories.
>
> *(Williams 1928, 3–4)*

Williams helpfully numbered and labeled his arguments, so let us see two examples of what he regarded as overwhelming and decisive proofs.

Argument 1 is called "The Population of the World." The thrust of the argument is that the human population is too small, if we

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believe that humanity has existed in excess of 100,000 years, as evolution would seem to require. He cites census data from 1922 to put the human population of the world at 1,804,187,000. If we imagine starting with a single human pair, which then doubles to 4 people, then 8, and so on, then it is a routine calculation to show that between 30 and 31 doublings are necessary to reach a population of 1.8 billion. He then carries out some calculations to show that if we assume the biblical chronology to be correct, which, he says, places the human population at two 5,177 years previously, then we conclude humanity doubles its population every 168.3 years. He carries out a separate calculation to arrive at the conclusion that the Jewish people have doubled their numbers every 161.251 years, and he makes much ado of the closeness of these numbers.

This is a prelude to the argument's climax, which goes like this:

> [L]et us suppose that man, the dominant species, originated from a single pair, only 100,000 years ago, the shortest period suggested by any evolutionist (and much too short for evolution) and that the population doubled in 1612.51 years, one-tenth the Jewish rate of net increase, a most generous estimate. The present population of the globe should be 4,660,210,253,138,204,300 …. In these calculations, we have made greater allowances than any self-respecting evolutionist could ask without blushing. And yet, withal, it is as clear as the light of day that the ancestors of man could not possibly have lived 2,000,000 or 1,000,000 or 100,000 years ago, or even 10,000 years ago; for if the population had increased at the Jewish rate for 10,000 years, it would be more than two billion times as great as it is. No guess that was ever made, or ever can be made, much in excess of 5177 years, can possibly stand as the age of man. The evolutionist cannot sidestep this argument by a new guess. QED. *(Williams 1928, 11)*

To clarify, if humanity originated as a single pair 100,000 years ago and doubled its numbers every 1,612.51 years, then that makes just over 62 doublings. If you raise 2 to the 62 power, the result is in the neighborhood of 4.6 quintillion, as Williams asserts.

Williams is quite taken with this sort of thing, and he develops his full argument over nearly four full pages. I have chosen the one paragraph above as representative both of the argument itself and the writing style Williams employed.

However, I am sure that in the time it took you to read that paragraph, you noticed that Williams based his calculations on a highly dubious assumption. Specifically, he assumed that the human doubling time has been constant throughout our history as a species, but this is not reasonable. Modern scientific estimates suggest that species *Homo sapiens* first appeared roughly 200,000 years ago, but for most of those years the human population was either flat or even decreasing. After all, for most of human history life was nasty, brutish, and short, to use Thomas Hobbes' memorable phrase. Even well into the modern era there have been periods of declining human population, resulting from plagues and famines, for example. It is only with relatively modern advancements in medicine and nutrition that human populations double their numbers with any sort of alacrity. Once you dispense with the assumption of a constant doubling time, Williams' argument comes to look a bit silly.

Let us try one more. Argument 9 is called "Mathematical Probability." Here are some representative quotations:

> The evolution of species violates the rule of mathematical probability. It is so improbable that one and only one species out of 3,000,000 should develop into man, that it certainly was not the case. All had the same start, many had similar environments. … While all had the same start, only one species out of 3,000,000 reached the physical and intellectual and moral status of man. Why only one? Why do we not find beings equal or similar to man, developed from the cunning fox, the faithful dog, the innocent sheep, or the hog, one of the most social of all animals. Or still more from the many species of the talented monkey family? Out of 3,000,000 chances, is it not likely that more than one species would attain the status of man?
>
> *(Williams 1928, 23–24)*

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He does not explain why he thinks it is unlikely that human-like intelligence would evolve only once, but we get a clue to his reasoning from this:

> Evolution is not universally true in any sense of the term. Why are not fishes *now* changing into amphibians, amphibians into reptiles, reptiles into birds and mammals, and monkeys into man? If growth, development, evolution, were the rule, there would be no lower order of animals for all have had sufficient time to develop into the highest orders. Many have remained the same; some have deteriorated. *(Williams 1928, 25)*

After several pages of this, Williams presents his conclusion:

> To declare that our species alone crossed this measureless gulf, while our nearest relatives have not even made a fair start, is an affront to the intelligence of the thoughtful student. It does fierce violence to the doctrine of mathematical probability. It could not have happened. *(Williams 1928, 27)*

Those of you possessing some basic familiarity with evolutionary thinking will be scratching your head at this, since it is hard to understand what Williams is going on about. Every species possesses *some* attribute that makes it unique in the world. Williams could as easily have wondered why the giraffes alone have evolved such excessively long necks, or why it was just a few species of elephants that evolved excessively long noses. The long-term trajectory of evolution is governed by so many variables that it is impossible to predict which life forms and which adaptations will actually appear after millions of years.

The real action in Williams' argument seems to be in that middle quote, where he strongly implies that evolution entails a steady progression from lower to higher forms of life. This is a serious misapprehension, albeit a fairly common one. There is no concept of "higher" or "lower" animals in evolution, and there is certainly no notion that species are striving to ascend some ladder of progress.

We humans tend to be rather self impressed, and we naturally find it tempting to place ourselves at the top of creation. However, evolution only cares about brute survival. A successful animal is one that inserts many copies of its genes into the next generation, and one can do *that* while being not very bright at all.

We should also take note of Williams' casual references to the "rule of mathematical probability" and later to the "doctrine of mathematical probability." There are many available textbooks on probability theory (a statement that would have been no less true in 1928), but you will search them in vain for any reference to a central rule or doctrine at the heart of the subject. From the context, Williams seems to envision a bland statement to the effect that extremely improbable things do not occur, but even this would need a lot of caveats to be credible, since highly improbable things occur all the time. (There is an old saying that in New York City, which has a population of more than eight million people, million to one odds happen eight times a day.)

Williams' argument does bring up a number of interesting questions. For example, we might ask about the engineering constraints and selection pressures that determine whether or not human-like intelligence can evolve. Or we might remark on the phenomenon of evolutionary convergence, in which very similar adaptations arise in separate lineages independently of one another. To discuss those questions here, however, would be to give Williams' book more respect than it deserves.

Instead we should remark on the smug, arrogant tone of his writing, as well as the entirely unjustified bravado. Williams drapes his population calculations over many pages, but, as we have noted, his argument is killed stone dead by the utterly trivial observation that the human doubling rate is not constant over time. How could he not have noticed that? His argument about probability betrayed a complete ignorance of fundamental issues in both biology and mathematics. This is not the work of a man who has taken the views of his opponents seriously, who has devoted some time to

understanding the scientific and mathematical concepts about which he is writing, or who has tried to express himself with care and cogency.

This makes him entirely typical among anti-evolutionist writers.

1.5 THE SEARCH FOR AN IN-PRINCIPLE ARGUMENT

Mathematical anti-evolutionism is very ambitious in that it tries to rule evolution out of bounds in principle. If this approach succeeds, then all the circumstantial evidence in the world will be insufficient to save the theory.

To see what I mean, imagine that you are an attorney representing a client accused of murder. The prosecution has multiple pieces of evidence against your client: His fingerprints were found at the scene; he had access to the murder weapon; he had a strong motive; and a person matching his description was seen in the area at the time of the crime. You are trying to devise a defense strategy in response. There are two general approaches you might pursue.

The first approach is to challenge each piece of evidence individually: Your client had an entirely innocent reason for being at the scene prior to the crime, and that is why his fingerprints were found there; many people had a motive and access to the murder weapon; the description was so vague that it could have been anyone. You might generate reasonable doubt with such an approach, but a jury might also believe that the totality of the evidence suggests your client is guilty, even if each piece can be explained away individually.

The second approach is to argue that the suspect could not possibly have committed the crime: He has an iron-clad alibi for the time of the crime, or he was physically incapable of committing the crime because a childhood injury left him with only one functioning arm. These are examples of "in-principle" arguments. They imply that the accumulated evidence is irrelevant because your client simply cannot have committed this crime. If you can pull it off, this approach is more powerful.

As we shall see in Section 2.2, scientists point to many distinct lines of evidence in making the case for evolution, drawing on distinct sets of facts from every branch of the life sciences. The strength of the case comes not so much from any one line of evidence but from the many concordant lines drawn from numerous branches of science. Anti-evolutionists often dutifully pursue our attorney's first approach of challenging each line individually. They say a great many things in this regard, but scientists invariably find these arguments to be based on faulty facts or logic.

For anti-evolutionists, it would be so much more satisfying to have an in-principle argument against evolution, and mathematics seems like the place to turn to find such a thing. If you can carry out a calculation to show that evolution posits something impossible, or cite an abstract principle that says that large-scale evolution cannot occur, then you are freed from the burden of having to address the various lines of evidence individually. If the numbers do not add up, then the theory is wrong, and that is all there is to it.

Modern anti-evolutionists agree with Reverend Williams in saying that evolution fails the acid test of mathematics, and they have numerous arguments to offer on behalf of that view. We shall spend the remainder of this book considering those arguments.

We shall be forced to conclude that these arguments are entirely inadequate. Modern anti-evolutionists typically avoid the really gross errors of someone like Williams, but that is where the good news ends.

1.6 NOTES AND FURTHER READING

I have provided a detailed summary of the reliance on mathematical arguments in the recent ID literature in a previous paper (Rosenhouse 2016).

For discussions of the nuances and differences among various schools of anti-evolutionist thought, I recommend the books by Numbers (2007) and Scott (2009). For a discussion of the broader political and educational ambitions of anti-evolutionism, have a look at the books by Forrest and Gross (2003), and Berkman and Plutzer (2010).

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I remarked that modern evolutionary theory is marked by ferment over details coupled with confidence in the fundamentals, and also that new ideas seem to get introduced faster than they can be assessed and assimilated. A useful reference for both statements is the book edited by Pigliucci and Müller (2010). This book is essentially the proceedings of a conference held in 2008. The conference participants argued that there had been so many advances since the "modern synthesis" of the 1940s, that the time had come to speak seriously of an "extended synthesis." In their preface, Pigliucci and Müller write:

> The modifications and additions to the Modern Synthesis presented in this volume are combined under the term Extended Synthesis, not because anyone calls for a radically new theory, but because the current scope and practice of evolutionary biology clearly extend beyond the boundaries of the classical framework.
>
> *(Pigliucci and Müller 2010, viii)*

The book's contributors were mostly addressing very technical issues of interest to professional biologists, but did not at all challenge the aspects of evolutionary theory relevant to our concerns here.

The basic commitments of YEC are readily available on numerous websites. When I first started, I found the book by Morris and Parker (1987), who promote YEC, to be helpful, both for its clear presentation of creationist thought and for the generally childish tone of its writing. Though this book was written quite some time ago, YEC has not changed importantly in the ensuing years. Foundational texts for presenting the ID perspective are the books by Johnson (1991), Behe (1996), and Dembski (1999). More recent writings will be considered at the appropriate places in this book. Matzke (2009) is an excellent article establishing the fundamental continuity between YEC and ID.

In Section 1.3, I referred to the time I spent attending anti-evolutionist conferences and gatherings. I described my experiences and discussed some of the scientific and theological issues that naturally arose in a previous book (Rosenhouse 2011).

The history of the Scopes trial has been the subject of extensive scholarship. The recently updated book by Larson (2020) has been well received, though personally I find the older account by de Camp (1968) to be more engaging.

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The notion of "evolutionary convergence" has been widely debated among scientists. Paleontologist Stephen Jay Gould (1980) famously argued that the long-term trajectory of evolution is influenced by so many variables that were we to "replay the tape of life" starting from its ancient beginnings, it is unlikely that anything like humanity would evolve a second time. Simon Conway Morris (2004), also a paleontologist, demurred, arguing that the prevalence of convergence suggests the evolutionary process is so constrained that a second play of the tape would almost certainly bring us to essentially the same ending point. In my view, Gould had the better argument, but Conway Morris certainly has his points to make. A more recent treatment of these questions can be found in Losos (2018).

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