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We dedicate this book to Brooke and Elaine.

John Angus Campbell and Stephen C. Meyer
October 2003

Why Are We Still Debating Darwinism? Why Not Teach the Controversy?

John Angus Campbell

From the Scopes trial in 1925 through the action of the Kansas State Board of Education in 1999, the teaching of evolution in public schools has been a flashpoint in American education.[1] As in all long-standing controversies, positions harden and disputants speak chiefly to rally their own supporters. The debate ebbs and flows in public awareness until a local school board's decision catapults it once again into the lead story or back onto page one.

Many suppose that the debate over teaching evolution in public schools has gone on so long that it is going nowhere. But all things historical are hostage to change. Although its implications are not yet fully evident, something new has happened in the debate over the teaching of evolution. The advent of a modern scientific theory of intelligent design (ID) and a scholarly research community advancing this theory (the ID movement) have reenergized and are now redefining the character of this once-stalled controversy.[2] ID is a science, a philosophy, and a movement for educational reform.

As science, ID is an argument against the orthodox Darwinian claim that mindless forces—such as variation, inheritance, natural

selection, and time—can account for the principal features of the biological world.

As a philosophy, ID is a critique of the prevailing philosophy of science that limits explanation to purely physical or material causes.

As a program for educational reform, ID is a public movement to make Darwinism—its evidence, philosophic presuppositions, and rhetorical tactics—a matter of informed, broad, and spirited public discussion.

ID in all its senses has clear implications for the teaching of science, particularly biology, in the public schools—irrespective of one's view of the merits of the contemporary design argument. A central claim of the ID movement is that if science education is to be other than state-sponsored propaganda, a clear and principled distinction must be drawn between empirical science and the materialist philosophy that drives contemporary Darwinian theories of biological origins.[3]

As critics of ID are quick to point out, design arguments are not new. The basic insight on which such arguments rest is one side in an ancient philosophic controversy. That is, the complexity of the world order, particularly as seen in the study of life, appears to have been produced by intelligence or mind rather than by self-sufficient material forces. In ancient times, Heraclitus, Empedocles, Democritus, and Anaxamander upheld the self-sufficiency thesis, while Plato and Aristotle argued for mind.[4]

Why this argument should reemerge just now is easy to understand. At a time when contemporary cosmology speaks of "anthropic fine-tuning" and biology seeks to understand the "code of life" and the design of "molecular machines," the rise of the design hypothesis is as appropriate to our time as were the ideas of "natural selection" and "survival of the fittest" to the period of capitalist expansion and industrialization during the mid-nineteenth century.[5] "Information" and the nonmaterial products of intelligence are part of our daily speech, as is evident by our use of such terms as *software, programs, gigabytes,* or *RAM* and our questions about the "compatibility" of computers and printers.

What is new about the theory of intelligent design is the shock it administers through its creative restatement, in contemporary scientific terms, of an old and presumably extinct intellectual tradition. The origin of biological novelty was thought to have been identified, if not precisely by Darwin in 1859, then at least by neo-Darwinians in their 1940s synthesis. Yet design theorists insist that natural selection acting on random genetic mutation does not account for the fundamental morphological innovations in the history of life—whether novel organs, body plans, or cellular ma-

chines. Instead, they insist that actual design, not just a natural process mimicking design, is responsible for the complex features and systems found in living things. Though this view may not be new, the evidence and modes of analysis that design theorists use to advance it clearly are.[6]

Thus, the ID movement has only recently come into public awareness. Nevertheless, such awareness is growing rapidly as a result of the books and public speaking of Berkeley law professor Phillip Johnson; the book *Darwin's Black Box* by Lehigh University biochemist Michael Behe; William Dembski's *The Design Inference;* Jonathan Wells's *Icons of Evolution;* Paul Nelson's *On Common Descent;* and the scientific and philosophical essays of Stephen Meyer in anthologies such as *Science and Evidence of Design, Mere Creation,* and *Debating Design: From Darwin to DNA*. The growth of this intellectual movement has recently attracted prominent news stories in the *New York Times, Los Angeles Times, Wall Street Journal,* and the *National Post* (of Canada) as well an extensive two-part critique in the *New York Review of Books*.[7] Additionally, a recent Zogby poll shows strong support for the educational agenda of the design movement. Nearly 78 percent of those surveyed by Zogby favor including information about the scientific case for intelligent design in the public school science curriculum alongside standard Darwinian accounts of life's origins.[8] Congress has also expressed its support for teaching students about the scientific controversies that exist concerning biological evolutionary theory. The report language in the 2001 federal No Child Left Behind Act urges schools to adopt a science curriculum that "help[s] students to understand the full range of scientific views that exist" about controversial subjects "such as biological evolution" and "why such topics may generate controversy." Additionally, the Ohio State Board of Education recently adopted a provision in their state science standards requiring students to know why "scientists today continue to investigate and critically analyze aspects of evolutionary theory." While the Ohio State Board's decision did not mandate the teaching of intelligent design, it does require that students know about scientific criticisms of contemporary evolutionary theory. It also allows local school districts and teachers to present the theory of intelligent design if they so choose. One local school district, the Patrick Henry School District, has already announced its intention to teach students about the theory.[9]

Even so, many of the technical arguments of design theorists are not yet well known. The aim of this volume, *Darwinism, Design, and Public Education,* which itself has "evolved" or (if one prefers) was "redesigned" from a special issue of the journal *Rhetoric and Public Affairs,* is not to advocate the

theory of ID. Instead, this volume seeks to introduce science educators to the arguments of the design theorists and to those of prominent critics of ID, so that educators may consider the merits of the main pedagogical argument of this volume, namely, that science teachers would do well to "teach the controversy" or "controversies" over contemporary evolutionary theory.

Teachers who do so will advance public understanding of both the nature and rhetoric of science.[10] By the "rhetoric of science," I mean the study of the argumentative tactics employed by scientists not only in their scientific writing but also in their public and educational pronouncements. The rhetoric of science also seeks to identify presumptive substance and to detect probable weaknesses (or obfuscation) in a scientific argument or discourse.[11] In addition, the rhetoric of science seeks to foster civility in public discourse. On this score, it is important to remember John Stuart Mill's observation that in any controversy where the stakes are high, even the best people may present bad arguments with the best of intentions and, conversely, that those who do not prevail in public opinion may yet make many good arguments.[12]

Organization of the Volume

With this in mind, *Darwinism, Design, and Public Education* will seek to advance public discussion of science education by presenting arguments for and against a more inclusive, controversy-based biology curriculum. In order to do this, the book will also present arguments for and against both contemporary Darwinism and the theory of ID itself.

Darwinism, Design, and Public Education is divided into four parts and appendixes. The first part of the volume presents three essays arguing for a more inclusive approach to science education—indeed, one that would encourage science educators to teach students about scientific challenges to Darwinian theory and about the challenge posed to Darwinism by advocates of the theory of intelligent design. The second part includes several essays that provide scientific critiques of contemporary evolutionary theories or textbook presentations of these theories. The third part presents essays that develop the scientific case for intelligent design. The fourth part offers responses, chiefly critical, to the essays in the first three parts of the volume. The appendixes present both supporting documents about the controversy over the teaching of evolution in the public schools (including the transcript of a recent hearing of the U.S. Commission on Civil Rights

and an essay by Donald Kennedy) and a technical supplement to the case by Stephen C. Meyer, Marcus Ross, Paul Nelson, and Paul Chien on the Cambrian explosion.

Part I

Part I, "Should Darwinism Be Presented Critically and Comparatively in the Public Schools?: Philosophical, Educational, and Legal Issues," sets the agenda for the book. The question considered throughout the volume is "Should public school science teachers be free to teach the controversies over biological origins?" In my opening essay, "Intelligent Design, Darwinism, and the Philosophy of Public Education," I argue that teaching Darwin's theory of natural selection comparatively is the mode Darwin himself followed in the *Origin.* It is the traditional method used in the humanities, it is used to teach values, it is explicitly sanctioned by Mill's *On Liberty,* and it fosters student interest in science. Further, it helps teach the skills of analysis and critical deliberation that are central to democratic citizenship. In "Intelligent Design Theory, Religion, and the Science Curriculum," Warren A. Nord argues that liberal education in a pluralistic democracy requires the inclusion of competing points of view, including design theory in science classes, "not because it is a better or more reasonable theory than its naturalistic counterparts . . . [but] because we disagree about whether it is a better theory." That disagreement is of such a kind that educators are obligated to teach students about it. Throughout the essay, Nord develops his thesis: "By refusing to take seriously contending interpretations of nature, we teach science, in effect, as a matter of authority. Students typically come to accept its claims as a matter of faith in the scientific tradition rather than as a matter of critical reason."

The first part concludes with "Teaching the Controversy: Is It Science, Religion, or Speech?" In this essay, David DeWolf, Stephen C. Meyer, and Mark E. DeForrest argue that the law allows, and good pedagogy requires, public school biology teachers to "teach the controversies" over biological origins. They examine several proposed curricular changes that would rectify what they regard as the current imbalance in the biology curriculum. Their hypothetical teacher, John Spokes, would like to correct errors in present biology texts, expose students to evidential challenges to evolutionary theory, and discuss alternative theories of biological origins.[13] The authors ask, "Does the law allow him to do so?" They argue that it does, by showing that exposing students to an evidentially based critique of standard theories and to a similarly evidentially based case for alternatives

constitutes good science. They also show that presenting ID as an alternative theary does not constitute an establishment of religion. They suggest instead that refusal to allow Spokes to teach his subject in this more open way could well constitute a form of legally prohibited viewpoint discrimination.

Part II

The logic of the remainder of this volume follows directly from the educational and legal controversy that DeWolf, Meyer, and DeForrest address from the practical concerns of their hypothetical teacher, John Spokes. A teacher considering whether to "teach the controversy" will face practical pedagogical issues about the type of material that would be permissible, or desirable, to present.

In their legal essay, they ask a question: what exactly can Spokes (or any other public high school teacher) teach? Can teachers correct errors in the biology texts, including those that exaggerate the evidential support for Darwinism? Similarly, can teachers expose students to scientific critiques of neo-Darwinism and related evolutionary theories? If so, can they also tell students about alternative theories of origins, including specifically the theory of intelligent design? DeWolf, Meyer, and DeForrest argue that teachers may legally critique neo-Darwinism and present ID as an alternative. But this raises practical questions for science educators. First, what are the scientific critiques of textbooks or neo-Darwinism that students should know about? Second, what is the theory of intelligent design and what evidence, if any, supports it? And third, what scientific (or philosophical) critiques of design theory should students and educators know about?

The remainder of the book is organized mainly around these three questions to help science educators "teach the controversy" if they should so choose and to help policymakers assess the merits of the pedagogical argument made for this approach in Part I. Thus, Part IV includes not only substantive critiques of the scientific case in Parts II and III but also critiques of the pedagogical proposal—that is, the "teach the controversy" approach advocated in Part I.

Part II, "Scientific Critique of Biology Textbooks and Contemporary Evolutionary Theory," first seeks to establish that there are many errors in present biology texts, errors that in some cases overstate the evidential support for neo-Darwinism and chemical evolutionary theory. Part II also seeks to establish the existence of a significant evidential challenge to reigning evolutionary theories, even if that challenge goes almost unreported in basic texts. In short, it seeks to show that there is an evidential

challenge to contemporary evolutionary theory that students need to know about. (Additional aspects of this challenge are addressed in Part III in the articles that also make a positive case for intelligent design.)

In the first essay in Part II, Stephen C. Meyer and Michael Newton Keas identify an important error of omission, not only in textbooks, but also in most public discussions of evolutionary theory. Their essay, "The Meanings of Evolution," describes the multiple separate meanings associated with the term *evolution.* They recommend that teachers clearly define the separate meanings of that word and distinguish those meanings that enjoy strong evidential and scientific support from those that seem controversial or less conclusively established.

David Berlinski's "The Deniable Darwin" shows how, contrary to popular reports, qualified researchers do in fact have serious scientific objections to Darwin's theory. Berlinski uses probability theory to take exception to almost every major claim advanced for the explanatory power of Darwinian natural selection.

Turning specifically to the textbook issue, Jonathan Wells's essays, "Haeckel's Embryos and Evolution: Setting the Record Straight" and "Second Thoughts about Peppered Moths" (both published previously in science, or science education, journals), illustrate the pedagogically convenient errors tolerated in textbooks—in the case of Haeckel, for over a hundred years—by a science education regime that lacks motivation to correct its errors.

In "Where Do We Come From? A Humbling Look at the Biology of Life's Origin," Massimo Pigliucci summarizes the status and prospects of current origin-of-life research. He critiques many current texts for their overly sanguine discussion of chemical evolutionary theories of the origin of life. (Pigliucci is not a design theorist; his trenchant critique of ID is presented in Part IV.)

Finally, developing further the difficulties identified by Pigliucci and expanding on the Wells examples, Gordon C. Mills, Malcolm Lancaster, and Walter L. Bradley explore in "Origin of Life and Evolution in Biology Text Books: A Critique" how current developments in biochemistry and origin-of-life studies contradict many current textbook presentations of chemical evolutionary theory.

Part III

In Part III, "The Theory of Intelligent Design: A Scientific Alternative to Neo-Darwinian and/or Chemical Evolutionary Theories," design theorists seek to bring the comparative or controversy-centered model set forth in

Part I to a critical point of development. They defend the comparative explanatory power of their theory with evidence from biochemistry, molecular biology, developmental biology, genetics, and paleontology. Here, design theorists argue their theory provides a better explanation of familiar biological phenomena—such as the information stored in DNA and proteins, molecular homologies, the complex structure of molecular machines, and the pattern of appearance in the fossil record—than do competing neo-Darwinian or chemical evolutionary theories.

Stephen C. Meyer initiates this line of argument in "DNA and the Origin of Life: Information, Specification, and Explanation." He contends that intelligent design provides a better explanation than competing chemical evolutionary models for the origin of the information present in large biomacromolecules such as DNA, RNA, and proteins. Meyer shows that the term *information* as applied to DNA connotes not only improbability or complexity but also specificity of function. He then argues that neither chance nor necessity, nor the combination of the two, can explain the origin of information starting from purely physical-chemical antecedents. Instead, he argues that our knowledge of the causal powers of both natural entities and intelligent agency suggests intelligent design as the best explanation for the origin of the information necessary to build a cell in the first place.

In "Design in the Details: The Origin of Biomolecular Machines," the biochemist Michael J. Behe sets forth a central concept of the contemporary design argument, the notion of "irreducible complexity." Behe argues that the phenomena of his field include systems and mechanisms that display complex, interdependent, and coordinated functions. Such intricacy, Behe argues, defies the causal power of natural selection acting on random variation, the "no end in view" mechanism of neo-Darwinism. Yet he notes that irreducible complexity is a feature of systems that are known to be designed by intelligent agents. He thus concludes that intelligent design provides a better explanation for the presence of irreducible complexity in the molecular machines of the cell.

In "Homology in Biology: Problem for Naturalistic Science and Prospect for Intelligent Design," Paul Nelson and Jonathan Wells reexamine the phenomenon of homology, the structural identity of parts in distinct species such as the pentadactyl plan of the human hand, the wing of a bird, and the flipper of a seal, on which Darwin was willing to rest his entire argument. Nelson and Wells contend that natural selection explains some of the facts of homology but leaves important anomalies (including many

so-called molecular sequence homologies) unexplained. They argue that intelligent design explains the origin of homology better than the mechanisms cited by advocates of neo-Darwinism.

Next, Stephen C. Meyer, Marcus Ross, Paul Nelson, and Paul Chien, in "The Cambrian Explosion: Biology's Big Bang," show that the pattern of fossil appearance in the Cambrian period contradicts the predictions or empirical expectations of neo-Darwinian (and punctuationalist) evolutionary theory. They argue that the fossil record displays several features—a hierarchical top-down pattern of appearance, the morphological isolation of disparate body plans, and a discontinuous increase in information content—that are strongly reminiscent of the pattern of evidence found in the history of human technology. Thus, they conclude that intelligent design provides a better, more causally adequate, explanation of the origin of the novel animal forms present in the Cambrian explosion. Meyer and his coauthors also note that (whatever its explanation) this dramatic event in the history of life is, with very few exceptions, not discussed in American basic biology texts.

With his colleagues having established an evidential basis for considering an inference to intelligent design, William A. Dembski provides a summary of his theory of design detection. In "Reinstating Design within Science," Dembski argues that advances in the information sciences have provided a theoretical basis for detecting the prior action of an intelligent agent. Starting from the commonsense observation that we make design inferences all the time, Dembski shows that we do so on the basis of clear criteria. He then shows how those criteria, complexity and specification, reliably indicate intelligent causation. He gives a rational reconstruction of a method by which rational agents decide between competing types of explanation, those based on chance, physical-chemical necessity, or intelligent design. Since he asserts we can detect design by reference to objective criteria, Dembski also argues for the scientific legitimacy of inferences to intelligent design.

Part IV

In Part IV, "Critical Responses," several prominent scientists and scholars critique either the substantive arguments for intelligent design or the case for exposing students to these arguments, or both. Though most responses are sharply critical, a few support more inclusive science education and a few support some of the substantive scientific claims of ID advocates.

Phillip Johnson, the one ID proponent included among the respondents, supports both.

In the first response, Celeste Michelle Condit offers a spirited critique of Meyer's argument to design based upon the presence of information in DNA. She also dismisses ID as unscientific and defends a Darwinism-only approach to science education (though perhaps one taught less dogmatically than at present). She bases her critique in part on her studies of public controversies over genetic engineering. She also offers advice on how religion might take itself more seriously by relinquishing any claim to be an empirical discourse and warns of the dangers of religion in the public sphere, particularly in the classroom.

David Depew critiques the basic idea of design in biology as framed by the design theorists, though he acknowledges, with the ID authors, that a robust debate about the mechanisms of evolution is currently under way within biology. Depew notes, however, that Darwinism is not Darwin's science alone but a family of theories often holding very different views of the mechanisms and tempo of evolutionary change. He thus faults the ID proponents in Part III, specifically Michael J. Behe, for failing to acknowledge the promise of other fully naturalistic proposals—in particular, self-organizational models—that he believes can explain the origin of biological information and complexity. The concluding section of his essay suggests a provisional openness toward a larger role for deliberation in the science classroom.

Bruce H. Weber critiques Behe's notion of "irreducible complexity" and challenges Behe's claim that no intermediate structures have been reported in the literature. On matters of educational policy, Weber has recently developed a university course in which the ID model and the Darwinian model are contrasted and critiqued.

Massimo Pigliucci then provides a pointed response to Dembski's argument for "specified complexity" and offers a clear account of the meanings of design in biology. He shows why he believes that inferences to intelligent agency rest on bad science and faulty logic. Pigliucci has long maintained that, since only Darwinism is science, only Darwinism should be taught in public schools.

Philosopher Michael Ruse, whose testimony was instrumental in Judge Overton's decision in the Arkansas creation–science case, defends himself against the charge of inconsistency leveled in my essay in Part I. He reiterates the soundness of the fundamental tenets of neo-Darwinism and of his view that "professional Darwinism" is science and ID is not.

Eugene Garver urges that only Darwin's theory should be taught in the public schools and taught "dogmatically and intelligently." Garver critiques the central contentions of the "teach the controversy" model, including the notion that any important connection exists between the teaching of science and the democratic practices of the larger society.

Though William Provine disagrees with the substance of the case for ID, he does favor a more inclusive approach to teaching the controversy. He thus disagrees with the educational proposals of both Eugene Garver and Alvin Plantinga (see below). Provine argues that living organisms only appear designed. He reaffirms that this appearance can be fully explained by neo-Darwinian theory. Unlike many prominent neo-Darwinians, however, Provine encourages teachers to tell their students about scientific criticism of neo-Darwinism as well as the arguments for intelligent design. Having repeatedly invited Phillip Johnson for debates before his classes at Cornell, Provine is critical of science educators who refuse to debate the merits of Darwinism in the classroom.

In sharp contrast to Garver, who favors teaching only Darwinism, and Provine, who favors teaching both Darwinism and design, Alvin Plantinga challenges the propriety of teaching Darwinism at all. Plantinga argues that, in a pluralistic culture, elementary fairness and justice require that public schools cannot teach as true what its citizens hold—as part of their basic beliefs—to be false.

John Lyne reflects on the Darwinian debate from his experience in graduate and undergraduate teaching in the humanities and calls attention to how theories of the nature of things, no matter how scientific, always carry implicit worldview commitments.

Steve Fuller, while expressing caution on all metaphysical positions, sees no greater danger in ID than in Darwinism. On educational and cultural levels, he sees a positive role for ID, lending his support to the ID critique of Darwinism and to its effort to bring about a productive alliance between science and democratic culture.

Brig Klyce and Chandra Wickramasinghe (Wickramasinghe was a witness for the defense in the Arkansas creation-science case in the early 1980s) illustrate the pluralism of the design perspective in that, while they reject the idea of a designer, they also reject neo-Darwinist theory and fully accept the ID critique of conventional Darwinian science. They also support the "teach the controversy" model. Following the earlier lead of Sir Fred Hoyle, Klyce and Wickramasinghe make a positive case for space-

borne spores as the basis for the development and differentiation of life on Earth.

In a concluding essay, ID godfather Phillip Johnson engages Stanley Fish's critique of liberalism. He suggests that open discussion of the theory of intelligent design would advance pluralism and liberal political ideals in general.

By design, we chose respondents who would provide mainly negative assessment and critique of ID. The only exceptions are Phillip Johnson, who helped launch the ID movement; Alvin Plantinga, who has long questioned the rationality of Darwinism on philosophic grounds; and Steve Fuller, whose positive response seems more directed to the democratic implications of the ID view of science and society than to the philosophic or scientific merits of its argument.[14]

Appendixes

The appendixes present (A) the transcript of a briefing held before the United States Commission on Civil Rights Schools and Religion Project on 21 August 1998, in Seattle; (B) a short essay by Donald Kennedy, former president of Stanford University; and (C, D, and E) technical evidence supporting the case made by Meyer, Ross, Nelson, and Chien in "The Cambrian Explosion: Biology's Big Bang."

The briefing (appendix A) consisted of a panel on curriculum entitled "Curriculum Controversies in Biology." The two panelists were Stephen C. Meyer, a senior fellow of the Discovery Institute, and Eugenie Scott, who for many years has headed the National Center for Science Education. The testimony of Meyer and Scott, and their responses to the extensive questions posed by the commissioners, particularly on the issue of possible viewpoint discrimination in the current science curriculum, provides a clear contrast between the philosophic assumptions and educational practices advocated by the two principal sides in this dispute.

Donald Kennedy's essay (appendix B) summarizes the rationale for the "Darwin only" position presented in the National Academy of Science's booklet *Teaching About Evolution and The Nature of Science,* which was written by a group of research scientists and high school teachers headed by Kennedy.

Appendixes C, D, and E provide information and analysis supporting the paleontological arguments made by Meyer, Ross, Nelson, and Chien in their essay, "The Cambrian Explosion: Biology's Big Bang."

An Objection to the Organization of This Volume

Clearly, even with a preponderance of negative responses, this volume gives greater voice to the arguments of the ID advocates and to those advocating discussion of ID in the public school curriculum. To some, this may seem unbalanced and even gratuitous. And indeed, from one perspective, the best plan for this volume might have been to assign equal space to each side. The problem with that approach, as Darwin himself was quick to realize, is that novelty requires time and repetition to sink in.[15] Darwin's uphill battle to distinguish his own position in the public mind and in the understanding of his peers from that of his predecessors is our warrant for giving greater space (in Parts I–III), but far from an unchallenged right of way (Part IV), to ID, the less familiar side in the current debate. Darwin, as in the case of contemporary defenders of ID, was not introducing a new idea for the first time but was attempting to establish his own explanation of the old and long discredited idea of "evolution." Darwin's challenge was to get his colleagues and the public to see how his proposed mechanism ("natural selection") put the whole argument for evolution on a very different footing from the arguments advanced by his grandfather, Erasmus Darwin, Jean Chevalier Lamarck, Robert Chambers, and Herbert Spencer.

Like Darwin's theory, as perceived by his peers and by the public in 1859, the contemporary argument for design is also a restatement of an old position. A key challenge for ID advocates is to distinguish their position, grounded in the information sciences and the method of "inferring to the best explanation," from its predecessors. Even as reviewers of the *Origin* identified it with earlier and discredited theories, so one will find in this volume respondents whose evaluation of intelligent design echoes the language of Darwin's initial reviewers.[16] The critical reaction here of the majority of respondents underscores the propriety of the organizational plan of this volume, providing balance to the dispute in a manner that is contextual and qualitative, not merely quantitative. Since Darwinism long ago replaced design as the established paradigm in science, readers of this volume are presumed to have learned Darwin's argument in school, as did their fathers and mothers, grandparents, and even great-grandparents.[17] For most readers, these pages will provide a first encounter with an alternative to the established paradigm by qualified authors who believe that Darwinism is false and wish to see it replaced. Our procedure of presenting the theory of intelligent design in detail and in the words of its defenders, even at the expense of not providing equal space for objections from the

established theory, is one that Darwin's contemporary, John Stuart Mill, in that other classic of 1859, *On Liberty,* recognized as just and equitable when evaluating an idea that has been marginalized and generally rejected.[18] It is a tribute to the quality of the respondents whose critiques appear in Part IV that, necessarily brief as are their comments, they omit no objection to ID whether considered as science, as philosophy, or as a program for educational reform.

Two Additional Matters

Two additional considerations, the claim of ID to be science and the timing of this volume—why revisit this dispute?—deserve comment.

Is Intelligent Design Science?

However one weighs the claim that design theory is not, and cannot be, science—a decisive claim for some—that claim should be considered both in light of the design arguments advanced in Part III and in light of the historical character of the philosophy of science. Pronounced as is the parallel between Darwinism and design, at least in audience reaction and burden of proof, the parallel is nowhere more pronounced and symmetrical than on the charge that ID is not science. Various initial readers of Darwin's theory rejected it as science and regarded his book as an example of theorizing unrestrained by evidence.[19] John Herschel, an intellectual mentor whom Darwin highly respected, crushingly rejected the idea of natural selection.[20] Louis Agassiz characterized Darwin's theory "as a scientific mistake, untrue in its facts, unscientific in its method and mischievous in its tendency."[21] In his subsequent editions and particularly in his private letters, Darwin took pains to convince his readers that what he was offering was substantive science and not wish fulfillment.[22]

Darwin's hostile or skeptical readers were, in a way, correct. What Darwin was presenting was not just an argument for evolution by natural selection but a revolution in scientific method.[23] In 1859, few would have questioned whether design arguments were scientific; then, inferences to design in books on "natural philosophy" were commonplace and unremarkable. The book from which Darwin learned scientific method and logic, Herschel's *Preliminary Discourse,* legitimated the design inference as one of the highest motives for studying science.[24] By his careful attention to it in the *Origin,* Darwin certainly treated design as a potentially warranted scientific inference.[25]

A present reader, however, may conclude that ID is not and cannot be science because it draws an inference to an unobservable, nonmaterial cause. Yet that reader has no greater certainty (to be consistently comparative about it) than the most ardent ID advocate that such a conclusion will be acceptable to scientists or philosophers of science in a hundred years—or for that matter, in twenty-five years, ten years, or next week. If the *Origin* provides any basis for surmise, it is within the bounds of historical possibility that a perspective that would at first glance strike today's best scientific and philosophic minds as the height of the ridiculous may eventually be accepted.

Not that novel arguments in science or in life are necessarily good, any more than traditional or familiar ones are necessarily bad. Ernst Mach clearly held scientific views that Max Planck judged as reactionary, and it was these same "reactionary" views that nurtured Einstein's imagination and helped him formulate his epochal and notably counterintuitive theory of relativity (or to give it its proper name, the theory of invariance).[26] Views of science judged, for whatever reasons, as unacceptable to the scientific regime of a particular country or time have repeatedly shown themselves to be capable, under the right circumstances or in the right minds, of generating science as good as, or better than, the "legitimate science" of many an established paradigm.[27] As Darwin might have said, the rejection of novelty by a science establishment with a deep cultural and metaphysical investment in an alternative point of view seems to be part of some more general rhetorical law.

In any case, as Thomas Kuhn pointed out, debate about the methodological rules of science often forms part of the practice of science, especially during times when established paradigms are being challenged.[28] Those who reject the "teach the controversy" model on the grounds that ID violates the current rules of scientific practice only beg the question. The present regime of methodological rules cannot prevent controversy for the simple reason that those rules may themselves be one of the subjects of scientific controversy. Why not let students know about these debates as well? In the current context, that means letting students know that some scientists and philosophers (see, for example, Stephen C. Meyer's conclusion in his essay "DNA and the Origin of Life") challenge the convention of methodological naturalism and its prohibition on explaining phenomenon by reference to intelligent causes.

I have already mentioned the important role of computers and concepts from the information sciences in creating a climate of opinion that has

fostered a reemergence of design language in science.[29] Clearly, the theoretical imagination of our time is neither that of Darwin's nor that of the neo-Darwinian synthesis of the 1940s. But why, even given that fact, is it productive to revisit what, at least in outline, must seem to be a very familiar debate? The issue needs reconsideration because science education, like science itself, must be constantly subject to revision in light of the demands of new generations of students and of new scientific knowledge. Indeed, advances in molecular biology, paleontology, and the information sciences have placed traditional questions of design on a new footing.

The Changing Roster of Disputants

An additional reason for revisiting the dispute is that the disputants have changed. The ID movement, comprising as it does academics, scientists, philosophers, humanist educators, and interested laypeople, is certainly not the same, except for purposes of histrionic exaggeration, as the young-earth, six-literal-days "creation science" of the past. Who is the designer? Who knows? ID advocates, unlike creation-science advocates, sign no confession of faith, nor could they gain agreement among themselves on one credo, were anyone foolish enough to suggest it. In the ambience of ID's "broad tent" and amid lively disagreements on just about every fundamental issue except the need to critique Darwinism and to affirm the detectability of design in nature, one will find persons of many philosophic perspectives and metaphysical commitments.

Given the fundamental changes that have overtaken the parties to this dispute, the dispute itself must be reconsidered.

The changes now reframing this historic debate are both intellectual and social. The appearance of Thomas Kuhn's 1962 treatise, *The Structure of Scientific Revolutions,* sparked an intellectual revolution, which he himself called "a paradigm shift," in both the philosophy of science and the social understanding of science.[30] Contrary to the positivist climate that characterized science at the opening of the twentieth century—which *Sputnik* revitalized and carried to the U.S. public schools well into its latter decades—in the early twenty-first century science is now acknowledged to be a highly interpretive enterprise.

The current interpretive understanding of science has developed through roughly three broad stages. In the heroic age of modern science, the seventeenth century, Bacon argued that theories emerged inductively from data.[31] We see remnants of this view of science even in Darwin's

Origin, where he spoke of how he began his species research "by patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing on it." During all that time of fact collecting, he refrained chastely from any theorizing. "After five years' work I allowed myself to speculate on the subject."[32]

In the era of positivism, from the mid-nineteenth century through the mid-twentieth, theorizing was recognized as having a far more central role in science than Bacon gave it, but theory evaluation was still thought to be unproblematically data-determined.[33] Huxley, for example, kept trying to think of crucial experiments that would prove Darwin's theory up or down.[34] Darwin politely discouraged him, arguing that Huxley did not grasp that his argument was comparative.[35]

In the neo-positivist era, roughly from the 1940s until Kuhn, theory evaluation and explanation were thought to be pretty much what Huxley took them to be: formulaic. Karl Popper taught that one could test a scientific theory by making predictions and then determining by observation whether the predictions confirmed or falsified one's theory.[36] Similarly, Carl Hempel argued that successful explanation occurred when one could deduce an event or phenomenon from a set of specified initial conditions and laws.[37] Both of these models, for all their partial truths and separate and collective strengths, portrayed testing theories and formulating explanations as something that could take place without considering the merits of competing theories and explanations. More recent developments in the philosophy of science, from Imre Lakatos's "Falsification and the Methodology of Scientific Research Programs" to Peter Lipton's *Inference to the Best Explanation,* have stressed the comparative and competitive nature of theory evaluation.[38]

A key development in understanding theory evaluation since Hempel and Popper has thus been the realization that science rests on argument, that much of the substance of science hinges on which theory among a group of competitors can provide the best interpretation of a set of data.[39] It is in this sense—the sense of the comparative value of explanation and argument within the complex interrogation of nature we call science—that contemporary scientific theory has added its discriminating color to the terms *scientific reason* or *scientific method* or just plain *science.* Because theory evaluation is now understood to be a comparative process, the argumentative back-and-forth recognized under the ancient disciplines of dialectic and rhetoric has now been elevated within science to a dignity it has not enjoyed since the overturn of Aristotelian science in the seventeenth

century.[40] Though some have contended that recognition of the role of informal argument amid the rigors of science makes science "mere rhetoric," it does nothing of the kind.[41] Rhetoric itself included logic, nor is there anything "mere" about knowing enough to participate meaningfully in a scientific discussion or, as a citizen bystander, knowing enough to know what the argument is about.[42]

The implications of these developments in the philosophy of science for the education of tomorrow's scientists are anything but academic or abstract. For a modern scientist, early education in comparative argument, and persuasive communication forms a core of foundational skills indispensable for future achievement—irrespective of the content of tomorrow's theories. A contemporary scientist must know not only how to put a hypothesis forward but how to put it across.[43] A scientist gets grants.[44] Having gotten them and done the experiments, the researcher must interpret the results, show what has been discovered, draw out its implications, and show why funding for more experiments, or experiments of a new kind, is now necessary. In addition, the scientist must defend his or her work against possible counterfindings of other independent peers working in the same field, sharing the same love of truth and competing for the same research dollars, promotions, prizes, and recognition. In today's world, nature never speaks but with a human voice and never more authoritatively than after argumentation between research rivals leaves no refuge but consensus—if sometimes grudgingly and if only for now.[45]

Training in argument, essential for the education of tomorrow's scientists, is no less important for tomorrow's citizens. One has only to think of the stressful necessity that modern medicine routinely places on laypeople to challenge expert advice and seek a second or third opinion to realize that lay skepticism of natural science is a practical reality in our world—and on balance a good thing.[46] What better place than the biology class to understand the appropriateness of skeptical questions directed toward scientific authority and to learn how, from asking such questions in medical contexts, lives have been saved, and in research contexts, new discoveries made?

Nor is the thesis persuasive that critique must be postponed until the student achieves mastery.[47] Jerome Groopman tells the story of how he and his wife, though both doctors and reluctant to challenge the opinion of fellow professionals, twice did so and thereby saved the life of their son. He also cites the story of a couple that, with no formal medical education at all, made a similar challenge with similar results.[48] The presentation of

science and the critique of scientific reasoning, including the possibilities for error in fact, inferences, or theories, need to be taught simultaneously. Science, over and over again having proven itself indispensable to society, by that very feat has underscored the need for critical thinking about science to be integrated into the fabric of scientific education.[49]

The Merits of Comparison, Criticism, and Competition

By showing that scientific reasoning is not one but many and does not stand alone but on a continuum with the reasoning of common life, the critical comparative model makes science education more rigorous and socially responsive than the Darwin-only model and at the same time addresses legitimate concerns of an increasingly informed, skeptical, and impatient public. The debate over educational vouchers continues. The home-schooling movement originated by religiously conservative parents has grown and diversified to include nonreligious parents fed up with the inability of schools to teach values or even to teach, placing increasing pressure on public education.[50] Whether public education can sufficiently reform itself to win the confidence of the people whom it is supposed to serve is an open question—and the debate about biological origins, while far from the whole, is an important part of it. The science that generated the debate over evolution has changed. So has the society that continues the debate. There is hope for a fresh beginning. What for Hannah Arendt was the political equivalent of grace is, just possibly, not in vain.[51]

In the late 1950s, at the height of positivism in science and under the urgency of national defense, the idea that a value-neutral science—even if it touched on questions of ultimate beginnings, endings, and the narrative that governed meanings—could be taught unproblematically seemed reasonable to many thoughtful people.[52] Those who dissented were regarded as a fringe minority whose opinions had already been assigned to history's dustbin and whose opposition would abate with the spread of education and indoor plumbing. In the years since *Leave It to Beaver* and "Duck and Cover," those who dissent from Darwin's master narrative, or variants thereof, have grown in number and self-confidence. Many turn out to be remarkably well educated and not particularly rural. A more important fact is that at the dawn of the twenty-first century the United States is clearly and robustly a pluralistic culture, becoming more diversified and energetic in its pluralism all the time.[53]

Many complain, "But teaching evolution is not an issue in Europe, or even in Canada; the issue is peculiar to the United States." And perhaps it is. But the implication that we are invited to draw from this statement, that as Europe now is, so America is destined to become, or that Americans should be ashamed of themselves for not regarding the teaching of evolution as do Europeans, is as an argument as patronizing and uninformed as it is self-defeating. America has always been different from Europe both in its cultural pluralism and in the seriousness of its religious engagement. Yet these differences have not prohibited America from participating in the scientific or technological leadership of the world.

That Americans, with their diverse cultural backgrounds and worldviews (whether religious or secular), should disagree about an issue as fundamental as biological origins—that they should disagree for scientific, philosophical, or religious reasons (or even a mixture of all of these)—should neither surprise nor shame us. Nor should such disagreement paralyze our educational system as it seeks to educate students about the theory of Darwinian evolution, the scientific evidence relevant to adjudicating it, and possible competing interpretations of such evidence. Americans have often found ways to accommodate the pluralism of perspective that is inherent to our democratic culture. With the recognition that science, no less than politics or religion, necessarily involves the assessment of competing perspectives and interpretations, the pluralism that we have often incorporated into other modes of American life may now find a welcome home in the sometimes ideologically charged environment of our public school science classrooms.

There are three, and only three, options before us: teach evolution as Eugene Garver suggests, "dogmatically and intelligently"; avoid teaching it at all, as Alvin Plantinga suggests; or teach it in the spirit of the humanities as the current reigning, though contestable, theory and thereby honor in science education the integrity of informed dissenting opinion that grounds our American tradition of unity in diversity within politics, religion, and culture.

Notes

1. Edward J. Larson, *Summer for the Gods: The Scopes Trial and America's Continuing Debate Over Science and Religion* (New York: Basic Books, 1997); Edward J. Larson, *Trial and Error: The American Controversy over Creation and Evolution* (Oxford: Oxford University Press, 1989).

2. Nancy Pearcey, "We're Not in Kansas Anymore," *Christianity Today* (22 May 2000): 42–50; Nancy Pearcey, "Intelligent Design," *Touchstone: A Journal of Mere Christianity* 12 (July/Aug. 1999): 25–28.
3. For a good account of the engagement of ID scholars with other scholars on these issues, see Jon Buell and Virginia Hearn, eds., *Darwinism: Science or Philosophy? Proceedings of "Darwinism: Scientific Inference or Philosophical Preference"* (Richardson, Tex.: Foundation for Thought and Ethics, 1994). Also, an excellent conference entitled "Naturalism, Theism and the Scientific Enterprise: An Interdisciplinary Conference," held at the University of Texas, Austin (20–23 Feb. 1997), sponsored by the Philosophy Department of the University of Texas and organized by Robert Koons, brought together over a hundred scholars from the natural sciences, humanities, theology, philosophy, and law. Principal speakers were Michael Ruse, Darwin scholar and philosopher of science, University of Guelph; Alvin Plantinga, University of Notre Dame, critic of philosophic naturalism; Frederick Grinnell, University of Texas Southwestern Medical Center, philosopher of science; and Phillip Johnson, University of California School of Law, leader of the ID movement. Proceedings of the conference may be accessed at http://www.dla.utexas.edu/depts/philosophy/faculty/koons/ntse/ntse.html.
4. David J. Depew and Bruce H. Weber, *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection* (Cambridge: MIT Press, 1997), chap. 2, esp. pages 36–42; J. P. Moreland, *Christianity and the Nature of Science* (Grand Rapids, Mich.: Baker Books, 1994), 214–15.
5. M. A. Corey, *God and the New Cosmology: The Anthropic Design Argument* (Lanham, Md.: Rowan and Littlefield, 1993); John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986); Jeremy Campbell, *Grammatical Man: Information, Entropy, Language and Life* (New York: Simon and Schuster, 1982).
6. On the relation of Darwin's thesis to the neo-Darwinian synthesis, see Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley: University of California Press, 1984), 296–300; Leah Ceccarelli, "A Rhetoric of Interdisciplinary Scientific Discourse: Textual Criticism of Dobzhansky's Genetics and the Origins of Species," *Social Epistemology* 9: 91–112.
7. Phillip E. Johnson, *Darwin on Trial* (Downers Grove, Ill.: InterVarsity Press, 1997); Phillip E. Johnson, *Reason in the Balance: The Case Against Naturalism in Science, Law, and Education* (Downers Grove, Ill.: InterVarsity Press, 1995); Phillip E. Johnson, *Defeating Darwinism by Opening*

Minds (Downers Grove, Ill.: InterVarsity Press, 1997); Phillip E. Johnson, *Objections Sustained: Subversive Essays on Evolution, Law, and Culture* (Downers Grove, Ill.: InterVarsity, 1998); Michael Behe, *Darwin's Black Box: The Biochemical Challenge to Evolution* (New York: Free Press, 1996); William A. Dembski, *The Design Inference: Eliminating Chance through Small Probabilities* (Cambridge: Cambridge University Press, 1998); William A. Dembski and James M. Kushiner, eds., *Signs of Intelligence* (Grand Rapids, Mich.: Brazos Press, 2000); Jonathan Wells, *Icons of Evolution* (Washington, D.C.: Regnery, 2000); Paul Nelson, *On Common Descent* (Chicago: University of Chicago Evolutionary Monograph Series, forthcoming 2004); Michael J. Behe, William A. Dembski, and Stephen C. Meyer, *Science and Evidence of Design* (San Francisco: Ignatius, 2000); William A. Dembski, ed., *Mere Creation: Science, Faith and Intelligent Design* (Downers Grove, Ill.: InterVarsity Press, 1998); William A. Dembski and Michael Ruse, *Debating Design: From Darwin to DNA* (Cambridge: Cambridge University Press, forthcoming); James Glanz, "Darwin vs. Design: Evolutionists' New Battle," *New York Times,* 8 Apr. 2001; Teresa Watanabe, "Enlisting Science to Find the Fingerprints of a Creator," *Los Angeles Times,* 25 Mar. 2001; Gregg Easterbrook, "The New Fundamentalism," *Wall Street Journal,* 8 Aug. 2000; George Sim Johnston, "Designed for Living," *Wall Street Journal,* 15 Oct. 1999; Elizabeth Nickson, "God's Two Books: Nature and Scripture," *National Post of Canada,* 5 May 2001.

8. The Zogby poll may be viewed at http://www.reviewevolution.org. Among the new books on ID is Robert Pennock, *Intelligent Design Creationism and Its Critics: Philosophical, Theological, and Scientific Perspectives* (Cambridge: MIT Press, 2001).
9. "Ohio Plan Would Teach Evolution Debate," *New York Times,* 15 Oct. 2002, A15.
10. "Special Issue on the Intelligent Design Argument," *Rhetoric and Public Affairs* 1 (winter 1998).
11. For an excellent exposition of the central features of the rhetoric of science, see Marcello Pera, *The Discourses of Science,* trans. Clarissa Botsford (Chicago: University of Chicago Press, 1994).
12. John Stuart Mill, *On Liberty* (Harmondsworth: Penguin Books, 1980). On good people making bad arguments, see pages 116–17; on an aspect of truth being found on the side that may not prevail, see pages 108–15. "It is always probable that dissentients have something worth

hearing to say for themselves, and that truth would lose something by their silence" (111).

13. That there is a problem with contemporary textbooks has been documented by a study commissioned by the American Association for the Advancement of Science (AAAS). "According to a new study, not one of 10 widely used high school biology textbooks is acceptable overall. . . . The textbooks are so bad, the study's authors say, that the best advice they can offer to schools faced with a decision about buying new biology books is: Don't." AAAS spokesperson George Nelson said, "They present the content in a disconnected way . . . [and they] camouflage the important ideas with details and trivia." In general, the books focus too much on details and pay scant attention to overall concepts unifying these details into an understandable picture. From "Biology Textbooks Miss Big Picture," *Boston Globe,* quoted in the *Commercial Appeal,* Memphis, Tenn., 28 June 2000. Clearly the kind of debate over evolution that ID would encourage, as set forth in the various essays in this volume, would not only address this problem on a conceptual level but would help to provide the broad cultural support necessary to bring about reform.
14. Alvin Plantinga, *Warrant and Proper Function* (Oxford: Oxford University Press), 216–38.
15. Francis Darwin, ed., *The Life and Letters of Charles Darwin,* vol. 2 (New York: D. Appleton, 1911). To Lyell, 6 June 1860: "I can only hope by reiterated explanations finally to make the matter clearer" (111).
16. Anonymous, "Darwin on the Origin of Species," *North American Review* 90 (Apr. 1860): 475.
17. Larson, *Trial and Error,* introduction and chap. 1.
18. Mill, *On Liberty.* "On any of the great open questions just enumerated, if either of the two opinions has a better claim than the other, not merely to be tolerated, but to be encouraged and countenanced, it is the one which happens at the particular time and place to be in a minority. That is the opinion which for the time being, represents the neglected interests, the side of human well-being which is in danger of obtaining less than its share" (111).
19. Adam Sedgwick, "Objections to Mr. Darwin's Theory of the Origin of Species," *Spectator* (24 Mar. 1860), reprinted in David Hull, *Darwin and His Critics* (Cambridge: Harvard University Press, 1973), 155–70; Samuel Haughton, "Biogenesis," *Natural History Review* 7 (1869): 23–32, reprinted in Hull, *Darwin,* 217–27.

20. Darwin, *Life and Letters,* vol. 2. To Lyell, 12 Dec. 1859: "[Natural selection] 'is the law of higgeldy-piggeldy.' What this exactly means I do not know, but it is evidently very contemptuous. If true this is a great blow and discouragement" (37).
21. Louis Agassiz, "Prof. Agassiz on the Origin of Species," *American Journal of Science* 30 (July 1860): 154. Agassiz also observed, "I must protest now and forever against the bigotry spreading in some quarters, which would press upon science doctrines not immediately flowing from scientific premises and check its free progress" (from Agassiz's *Essay on Classification* [1859], 71–72, cited in Hull, *Darwin,* 446).
22. Changes in the various editions of the *Origin* are numerous. See Morse Peckham, ed., *The Origin of Species by Charles Darwin: A Variorum Text* (Philadelphia: University of Pennsylvania Press, 1959). See especially chapter 7, which Darwin added chiefly to rebut the objections of St. George Jackson Mivart, and chapter 15, the final chapter. Among the many friends and later readers to whom Darwin patiently explained his doctrine were Joseph Hooker, Charles Lyell, and Thomas Henry Huxley. See John Angus Campbell, "The Invisible Rhetorician: Charles Darwin's 'Third Party' Strategy," *Rhetorica* 7 (winter 1989): 55–85, esp. note 24. On the extreme doubts about the explanatory adequacy of natural selection, see Lyell's letter to Huxley, 17 June 1859, in Frederick Burkhardt and Sydney Smith, eds., *The Correspondence of Charles Darwin,* vol. 7 (Cambridge: Cambridge University Press, 1985), 305–7.
23. Michael T. Ghiselin, *The Triumph of the Darwinian Method* (Berkeley: University of California Press, 1969).
24. John F. W. Herschel, *A Preliminary Discourse on the Study of Natural Philosophy* (Chicago: University of Chicago Press, 1987). "The testimony of natural reason . . . places the existence and principal attributes of a Deity on such grounds as to render doubt absurd and atheism ridiculous" (7).
25. See especially chapters 6–8 in Charles Darwin, *On the Origin of Species* (Cambridge: Harvard University Press, [1859] 1964). Darwin's attention in these chapters to objections and to the appearance of design, particularly in organs of special complexity (see pages 186–94), shows in particular the seriousness with which he took design as a rival scientific hypothesis.
26. Steve Fuller, *Thomas Kuhn: A Philosophical History of Our Times* (Chicago: University of Chicago Press, 2000). "Mach highlighted fundamental objections to Newtonian mechanics that remained just as potent as when

they were first made nearly two centuries earlier, but had been suppressed from the professional training of physicists. The most famous of these objections pertained to the existence of absolute space and time, the ether, atoms, and even mass itself. Indeed Einstein credited Mach with keeping them alive long enough so as to suggest the need for what became relativity theory" (123).

27. One thinks of the rejection of the earth-centered view in the ancient world and of evolution itself, as well as of the contemporary ambiguous relation of alternative medicine or folk medicine to established medicine. Further, there is the ambiguous relationship of Goethe's science to established science and of the solid contributions of "idealist" or "essentialist" science, which in the hands of Linnaeus immeasurably advanced botany or in those of Cuvier helped establish the reality of past extinctions. Mill put the principle well: "Even in natural philosophy, there is always some other explanation possible of the same facts; some geocentric theory instead of heliocentric, some phlogiston instead of oxygen" (*On Liberty,* 98). For a good discussion of the scientific contributions of schools of thought operating from very different metaphysical premises, see Timothy Lenoir, *The Strategy of Life: Teleology and Mechanics in 19th-Century German Biology* (Chicago: University of Chicago Press, 1989). A suggestive recent example comes from the inventor of the DNA sequencer, Leroy Hood. Hood recently resigned his prestigious post at the University of Washington and delivered a stinging indictment that the blinkered department-centered specializations of universities make them unfit for contemporary biological research. In founding a new Institute for Systems Biology, he proposes to bring together biologists, computer scientists, engineers, physicists, and mathematicians. His research aim is to break with academic biology, take a systems approach, and by using computers look at the structure and behavior of cells or organisms and simulate their behavior as Boeing aircraft does an airplane. His research agenda seems markedly suggestive of what an ID program of scientific research might look like. Andrew Pollack, "Scientist At Work: Leroy Hood; A Biotech Superstar Looks at the Bigger Picture," *New York Times,* 17 Apr. 2001.
28. Thomas S. Kuhn, *The Structure of Scientific Revolutions,* 2nd ed. (Chicago: University of Chicago Press, 1970), 92–110.
29. Freeman Dyson, *Infinite in All Directions* (New York: Harper and Row, 1988). Dyson notes the reemergence of design in contemporary science and says a good word on behalf of the symmetry between the

anthropic principle in cosmology and design in biology: "The argument from design still has some merit as a philosophic principle. I propose we allow the argument from design the same status as the Anthropic Principle, excluded from science but tolerated in metascience" (297).

30. Kuhn, *Structure of Scientific Revolutions;* see also Fuller, *Thomas Kuhn.*
31. Michel Malherbe, "Bacon's Method of Science," in *The Cambridge Companion to Bacon,* ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996), 75–98.
32. Darwin, *Origin,* 1.
33. I use the term *positivism* in a broad sense to include the founding of the positivist program of thought by August Comte (1798–1857), especially his influential view that society progresses through theological, metaphysical, and positive stages of existence. I also include under the label "positivist" the specific school of twentieth-century positivists, the Logical Empiricists.
34. For Huxley's approach to science and how it differed from Darwin's, see Mario A. Digregorio, *T. H. Huxley's Place in Natural Science* (New Haven, Conn.: Yale University Press, 1984), 34–50.
35. Burkhardt and Smith, *Correspondence,* vol. 7 (letter of 2 June 1859), 301.
36. Karl R. Popper, *Logic of Scientific Discovery* (New York: Harper Torchbooks, 1965), 265–81.
37. Carl G. Hempel, *Aspects of Scientific Explanation* (New York: Harper and Row, 1965).
38. I. Lakatos and A. Musgrave, eds., *Criticism and the Growth of Knowledge: Proceedings of the Colloquium in the Philosophy of Science, London 1965* (Cambridge: Cambridge University Press, 1970), 91–195; Peter Lipton, *Inference to the Best Explanation* (New York: Routledge, 1991).
39. For a model of science based on argument, grounded in the analogy between scientific and legal argument, see Stephen Toulmin, *Human Understanding: The Collective Use and Evolution of Concepts* (Princeton, N.J.: Princeton University Press, 1972), 239–41.
40. Marcello Pera and William R. Shea, *Persuading Science: The Art of Scientific Rhetoric* (Canton, Mass: Science History Publications, 1991), 29–37.
41. For an authoritative explication and defense of the legitimate role of rhetoric/dialectic in science, see Pera, *Discourses;* see also Lawrence J. Prelli, *A Rhetoric of Science: Inventing Scientific Discourse* (Columbia: University of South Carolina Press, 1989); Alan G. Gross, *The Rhetoric of Science* (Cambridge: Harvard University Press, 1996); Charles Taylor,

Defining Science: A Rhetoric of Demarcation (Madison: University of Wisconsin Press, 1996); Jeanne Fahnestock, *Rhetorical Figures in Science* (Oxford: Oxford University Press, 1999).

42. Eugene Garver, *Aristotle's Rhetoric: An Art of Character* (Chicago: University of Chicago Press, 1994); see also Pera, *Discourses,* esp. chaps. 2 and 3.
43. Thomas F. Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press, 1999), 23–34; Margaret C. Jacob, ed., *The Politics of Western Science: 1640–1990* (Atlantic Highlands, N.J.: Humanities Press, 1990), 1–18, 81–102.
44. Stevenson and Byerly, *The Many Faces of Science,* 133–41. Leslie Stevenson and Henry Byerly, The Many Faces of Science (Boulder, Cdo: Westview Press, 2000), 133–41.
45. Pera, *Discourses,* 31–36.
46. Jerome Groopman, *Second Opinions: Stories of Intuition and Choice in the Changing World of Medicine* (New York: Viking, 2000), 9–37.
47. John Dewey opposed teaching science in a manner that reduced it to mere memorization and recitation, stripped of its critical component. See John Dewey, "The Relation of Science and Philosophy as a Basis of Education," in *John Dewey on Education: Selected Writings,* ed. R. D. Archambault (Chicago: University of Chicago Press, 1964), 19; Jürgen Habermas speaks tellingly to this point when he observes, "Uncritical mastery of existing disciplines offers no hope that learners will suddenly undergo a change in attitude, becoming skeptical and analytical about ideas, or they will suddenly be able to criticize after having hidden this virtue away for so long" (in Robert E. Young, ed., *Critical Theory of Education: Habermas and Our Children's Future* [New York: Columbia University Teachers College Press, 1990], 33). See also Martin Eger, "A Tale of Two Controversies: Dissonance in the Theory and Practice of Rationality," *Zygon* 23 (1988): 291–325.
48. Groopman, *Second Opinions,* chap. 1.
49. Stevenson and Byerly, *The Many Faces of Science,* 226–30.
50. Dissatisfaction with public schools, of course, takes many forms, including a desire for greater intimacy or bonding with one's children and concerns for safety, as well as dissatisfaction with prevailing public education. See Peter T. Kilborn, "Learning at Home, Students Take the Lead," *New York Times,* 24 May 2000. See also Linda Tagliaferro, "More Families Opt for Home Schooling," *New York Times,* 5 Dec. 1999.
51. Hannah Arendt, *The Human Condition* (New York: Doubleday Anchor Books, 1959), 212–23.

52. For an excellent discussion, see the introductory and concluding chapters of Larson, *Trial and Error.*
53. Elmore Leonard, "With or Without Prayer: One More Hail Mary Story," *New York Times Magazine,* 27 May 2000, 84–85. In the same number, see Jennifer Egan, "Where Meditation Is Going," 86–88. See also Edward Larson and Larry Witham, "The More They Learn the Less They Believe," *Nature* 394 (June 1998): 313.