

Biochemistry by design

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Creationists are attempting to use biochemistry to win acceptance for their doctrine in the public mind and especially in state-funded schools. Biochemist Michael Behe is a major figure in this effort. His contention that certain cellular structures and biochemical processes – bacterial flagella, the blood-clotting cascade and the vertebrate immune system – cannot be the products of evolution has generated vigorous opposition from fellow scientists, many of whom have refuted Behe's claims. Yet, despite these refutations and a decisive defeat in a US federal court case, Behe and his associates at the Discovery Institute continue to cultivate American supporters. They are also stepping up their efforts abroad and, worryingly, have achieved some success. Should biochemists (and other scientists) be concerned? We think they should be.

Introduction

For more than a decade, creationists at the Discovery Institute's Center for Science and Culture (CSC; www.discovery.org/csc) have promoted the idea that 'intelligent design' (ID) represents a new front in the scientific effort to explain the emergence of Earth's life forms. Continuing the tradition of earlier creationism, from which ID is a direct descendant [1], ID creationists aim their efforts at new areas of science. They direct variations of old creationist criticisms against developing fields of scientific investigation that manifest the always expected, but historically temporary, explanatory lacunae encountered in active scientific disciplines. Biochemistry is the area of science at which ID creationists have taken their sharpest aim. Biochemist and ID creationist Michael Behe, in his role as a CSC fellow, helped initiate and continues to be an integral participant in this rapidly expanding effort.

In *Darwin's Black Box*, published in August 1996, Behe argues that the (relatively new) discipline of biochemistry 'has pushed Darwin's theory to the limit' [2], necessitating a reassessment of the neo-Darwinian synthesis that revitalized evolutionary theory in the first half of the 20th century:

The beginnings of modern biochemistry came only after neo-Darwinism had been officially launched. Thus, (...) neo-Darwinism must be reconsidered in light of advances in biochemistry. The scientific disciplines that were part of the evolutionary synthesis are all nonmolecular. Yet for the Darwinian theory of evolution to be true, it has to account for the molecular

structure of life. *It is the purpose of this book to show that it does not* [2] [emphasis ours].

Because Behe sees the truth of evolutionary theory as contingent upon its explanatory adequacy at the molecular level, and because he asserts that in this it has failed, his logic implies that he considers evolutionary theory false, at least at the biochemical level. In *Darwin's Black Box*, Behe introduces his readers to a 'new' theory that he accuses mainstream scientists of refusing to acknowledge:

There is an elephant in the roomful of scientists who are trying to explain the development of life (...) 'intelligent design'. To a person who does not feel obliged to restrict his search to unintelligent causes, the straightforward conclusion is that many biochemical systems were designed (...) not by the laws of nature, not by chance and necessity; rather, they were *planned*. The designer knew what the systems would look like when they were completed, then took steps to bring the systems about (...). The conclusion of intelligent activity flows naturally from the data itself – not from sacred books or sectarian beliefs. Inferring that biochemical systems were designed by an intelligent agent is a humdrum process that requires no new principles of logic or science. It comes simply from the hard work that biochemistry has done in the past forty years (...) [2].

The problem for ID, however, is that neither Behe himself nor any of his creationist colleagues have done any of the hard work in the biochemistry to which he refers. Instead of original research, Behe's signature contribution to ID has been 'irreducible complexity' (IC), the claim that complex biological objects comprising functionally integrated parts, such as a bacterial flagellum, could not have been produced by natural selection but must have been deliberately and intelligently designed. But IC is not a new concept. Recounting the 1981 McLean vs Arkansas trial, creationist defense witness Norman Geisler recalls the testimony of fellow creationist Ariel Roth, who testified about the supposed insufficiency of natural selection to produce 'complex integrated structures': '[When] asked about other evidences for creation science, Roth mentioned several 'serious problems' with the evolution model (...) [that included the] difficulty of evolving complex integrated structures since each part of the integrated structure alone would be useless to the organism' [3]. Roth was referring to structures such as the respiratory system. Behe simply applies IC at the molecular level as although it were something new.

Much more important for understanding the ID movement – and Behe's involvement in it – is his use of

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the statements about ID (included earlier) from *Darwin's Black Box* in his speech at the Discovery Institute's God and Culture Conference of August 1996 [4], the very month in which the book was published. This event, the nature of which is clear from its title, reveals not only the core reason Behe is using biochemistry to promote ID, but also the way he and his associates actually understand it: as a religious belief, which, once given its rightful place in the educational and cultural mainstream, will reverse the damage that evolutionary theory, the product of science's naturalistic methodology, has done to western culture. To reverse this damage, however, Behe and his ID associates must first secure the acceptance of ID as science in the public mind and in state-funded schools. In 2005, Behe's efforts towards this goal earned him the starring role as the most prominent scientific witness for the defense in the first legal case contesting the teaching of ID, *Kitzmiller et al. vs Dover Area School District* [5].

Behe and his ID associates at the Discovery Institute have not only co-opted biochemistry as a weapon against evolutionary biology, but have also taken aim at all the major scientific disciplines supporting the modern theory: paleontology, geology and so on [6]. However, most recently, ID creationists have begun to use astronomy and cosmology in the service of their agenda [7]. Given their rejection of the naturalistic methodology of science, all disciplines – including physics and chemistry, in addition to science education in US public schools – are threatened. Moreover, they

have no plans to stop with science; as Phillip Johnson, the ID movement's advisor and de facto leader, asserts, 'Scientific naturalism has done its greatest damage in the arts and humanities' [8]. Accordingly, with the publication of CSC fellow Richard Weikart's book, *From Darwin to Hitler* [9], ID has expanded its efforts to include the distortion of history in addition to science.

Consequently, no part of the curriculum in American schools is safe from the ID movement's agenda. Neither is the US the only country on the ID movement's tactical map. Countries once considered safely beyond the borders of creationist influence, such as England, Germany and Russia [10], are finding themselves increasingly beset by a rise in indigenous interest in ID and the promotional efforts of American ID proponents.

The biochemist as creationist

As one of the founding fellows of the Discovery Institute's Center for the Renewal of Science and Culture, now the CSC, biochemist Behe has a decade-long history of involvement in promoting ID [11,12] (Table 1). Since the early 1990s, he has been a member of what the ID movement calls the 'Wedge', which is pursuing its agenda according to its correspondingly named 'Wedge Strategy' [1]. The Wedge is a cohort of creationists, including academics and a few professional scientists, organized to convince politicians and the larger body politic that 'Darwinism' (evolutionary biology) has collapsed and that there is a

Table 1. The development of modern creationism

Year	Event	Refs
1859	Charles Darwin publishes <i>On The Origin of Species</i>	[94]
1918	H.J. Muller describes Darwinian mechanism for evolving irreducibly complex biological machines	[17]
1925	'Scopes Monkey Trial' in Tennessee marks the beginning of American backlash against evolution ^a	[84]
1939	After great progress in genetics, H.J. Muller (Nobel laureate, 1946) specifies further the evolution of complex physiological structures and systems	[18]
1981	Creationist Ariel Roth testifies in <i>McLean vs Arkansas</i> that natural selection cannot produce 'complex integrated structures' ^b	[3]
1982	In <i>McLean v. Arkansas</i> , US District Court Judge William Overton rules against balancing evolution with creationism in state-funded schools ^c	[85]
1984	Creationist Charles Thaxton publishes <i>The Mystery of Life's Origin</i> , founding text of ID movement	[86]
1987	In <i>Edwards vs Aguillard</i> , US Supreme Court declares teaching creationism in state-funded schools unconstitutional	[87]
1988	Thaxton adopts 'intelligent design' as new label for creationism	[88]
1991	ID 'Wedge Strategy' begins with publication of Phillip E. Johnson's <i>Darwin on Trial</i>	[89]
1992	Michael Behe joins ID movement as participant in first ID conference at Southern Methodist University	[88]
1996	Discovery Institute establishes creationist Center for the Renewal of Science and Culture (now Center for Science and Culture) with Behe as a founding fellow	[1]
1996	Behe publishes <i>Darwin's Black Box</i>	[2]
1998	Center for the Renewal of Science and Culture produces its 'Wedge Strategy' document, outlining ID promotion over 20-year period	[1]
1999	Cell biologist Kenneth R. Miller publishes first book-length refutation of Behe's irreducible complexity argument, <i>Finding Darwin's God</i>	[90]
1999	ID creationists become involved in Kansas Board of Education's deletion of evolution from state science standards	[1]
2001	ID creationists lead effort to insert ID into Ohio state science standards	[1]
2004	January: Barbara Forrest and Paul R. Gross publish <i>Creationism's Trojan Horse</i> , used in Dover trial to document that ID is creationism	[1]
2004	October–November: Phillip Johnson tours 11 UK cities with young-earth creationist Andrew Snelling	[64,65,91]
2004	December: first lawsuit filed in US against teaching of ID creationism, <i>Kitzmiller et al. vs Dover Area School District</i> , in Dover (PA, USA)	[5]
2005	17–19 October: Michael Behe testifies for the defense in <i>Kitzmiller</i> trial	[41–43]
2005	20 December: in <i>Kitzmiller</i> Memorandum Opinion, Judge John E. Jones III issues ruling for plaintiffs that teaching ID creationism is unconstitutional in science classes in state-funded schools	[5]
2006	ID videos featuring Discovery Institute creationists are sent to every secondary school in England	[68]

^aTeacher John Scopes was convicted under Tennessee's Butler Act, which prohibited teaching 'any theory that denies the story of the Divine Creation of man as taught in the Bible, and to teach instead that man has descended from a lower order of animals'. The trial became the symbol of American cultural resistance to teaching evolution.

^bThis is an earlier creationist version of Michael Behe's concept of 'irreducible complexity'.

^cArkansas Act 590 (1981) required 'balanced treatment' of creationism and evolution in state-funded schools.

scientifically sound alternative: 'theistic science'. In theistic science, an intelligent designer (God) is the fundamental causal and explanatory instrument [1]. From the early 1990s to now, Behe has produced no data to support this argument. Yet his version of it remains the only potentially meaningful biological proposal of 'Intelligent Design Theory'.

Behe's proposal is that some, or many, biochemical systems are 'irreducibly complex' (IC); that, as such, they cannot have evolved by any Darwinian mechanism; and that, therefore, they must have been designed by an intelligent (purposeful) agent. He has applied this argument to, among other things, the vertebrate immune system, the blood-clotting cascade and 'the' bacterial flagellum (sic: there are hundreds of different variants among the numerous species of bacteria). Behe's original argument is best conveyed by direct quotation of *Darwin's Black Box*:

By irreducibly complex I mean a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning. An irreducibly complex system cannot be produced directly (that is, by continuously improving the existing function, which continues to work by the same mechanism) by slight, successive modifications of a precursor system, because any precursor to an irreducibly complex system that is missing a part is by definition non-functional. An irreducibly complex biological system, if there is such a thing, would be a powerful challenge to Darwinian evolution. Since natural selection can only choose systems that are already working, then if a biological system cannot be produced gradually it would have to arise as an integrated unit, in one fell swoop (...) [2].

Behe claims to have identified just such 'powerful challenges' in the form of IC systems at the subcellular level. By his gloss of Darwinian evolution, these objects cannot have evolved. Ergo, they have to have been designed 'in one fell swoop'. Unfortunately for the argument, this is immediately recognizable as the logical fallacy of false dichotomy. It is not necessarily true that if 'Darwinism' (as he presents it) is wrong, intelligent design must be right. There are, in principle, other theories, neither 'Darwinian' nor telic, that could be right, so far as the evidence available at any moment goes. Some philosophers of science never tire of reminding us of this. Behe's false dichotomy and other fallacies like it are given a comprehensive review by Dunkelberg (which is one of many similar reviews that have appeared since 1996) [13].

When the IC argument against evolution surfaced, its logical, factual and scholarly flaws were addressed quickly – not least by scientists (including one of us) who reviewed the book [14,15]. Those critiques have had no effect on the enthusiasm of the intended popular audience of the book. Behe's fellow ID-enthusiast, William Dembski, boasts of its continuing 15 000 sales per year [16]. Since 1996, Behe and his ID colleagues have responded to evidence of their gross error either by dismissing it without justification or by offering successive, marginal, re-definitions of 'irreducibly

complex' [13]. Those changes have not improved the argument, however. Beyond the false dichotomy, it had other flaws at the outset, and those, too, have been neither eliminated nor acknowledged.

Perhaps the basic substantive (rather than formal) flaw is the claim that IC systems or structures cannot have evolved gradually because all their parts (as defined) are necessary for the function, and must therefore have been there from the start. In the IC argument, any precursor system lacking any part would be functionless, and, of course, an evolving system is a system of precursors. In a functionless state, a 'precursor,' having no selective value, would fail to survive. This potential argument is not new; it was an early consideration of the Modern Synthesis (of classical evolutionary biology with genetics), first taken up by the eventual Nobel laureate Hermann J. Muller in 1918 [17]. This was in the context of the possible reversibility of evolution. Muller's analysis disposed of the non-evolvability argument very simply; he explained that incorporating an additional, but inessential, step or part to an existing structure or physiological system would be selectively positive so long as the change provided some improvement, however slight. It would thus favor survival. Thereafter, through other well-known processes (e.g. mutational loss of some other part of the now-improved system) that increment of function could become indispensable. The change in the system, that is, its evolution, would then have become irreversible. It would now be, as regards that function and as Behe dubbed it, irreducibly complex.

Entirely plausible processes exist, therefore, that have been long known in genetics, by which small and gradual changes to an initially simple, functional system can (and do) cause its complexity to increase and, at some point, to become 'irreducible' (Figure 1). Therefore, IC as Behe defines it is not un-evolvable, either in principle or in practice. Moreover, there is no reason why a currently IC system cannot continue to evolve by the mechanism described. Irreducible complexity and its acquisition (in the context of reversibility) were reviewed by Muller in 1939 [18]. This classic understanding, like others in the literature of evolution and genetics, has perhaps been misunderstood by Behe. (He is, by training and experience, neither an evolutionary biologist nor a geneticist.) In a recent article, Douglas Theobald dealt with this particular flaw in the IC argument and therefore in ID theory – neglect of Muller's mechanism – even in his title: 'The Mullerian two-step: add a part, make it necessary, or why Behe's 'irreducible complexity' is silly' [19].

Behe's assumption that there is such a thing as a single function that is permanently and unalterably associated with a particular biochemical system, or with a chemical (or for that matter a morphological) structure, is flawed on several levels. If it were correct in biological reality, there might be some merit in the IC argument, but it is not correct. The functions of biological and biochemical systems, like their parts, have changed continuously in the course of history. An old word to describe this reality was 'preadaptation', the supposed ability of a part, although its original 'function' was *a*, to serve alone in, or as an element of, a future, different function, *b*. This widespread phenomenon, but not its early interpretation, is so important in the

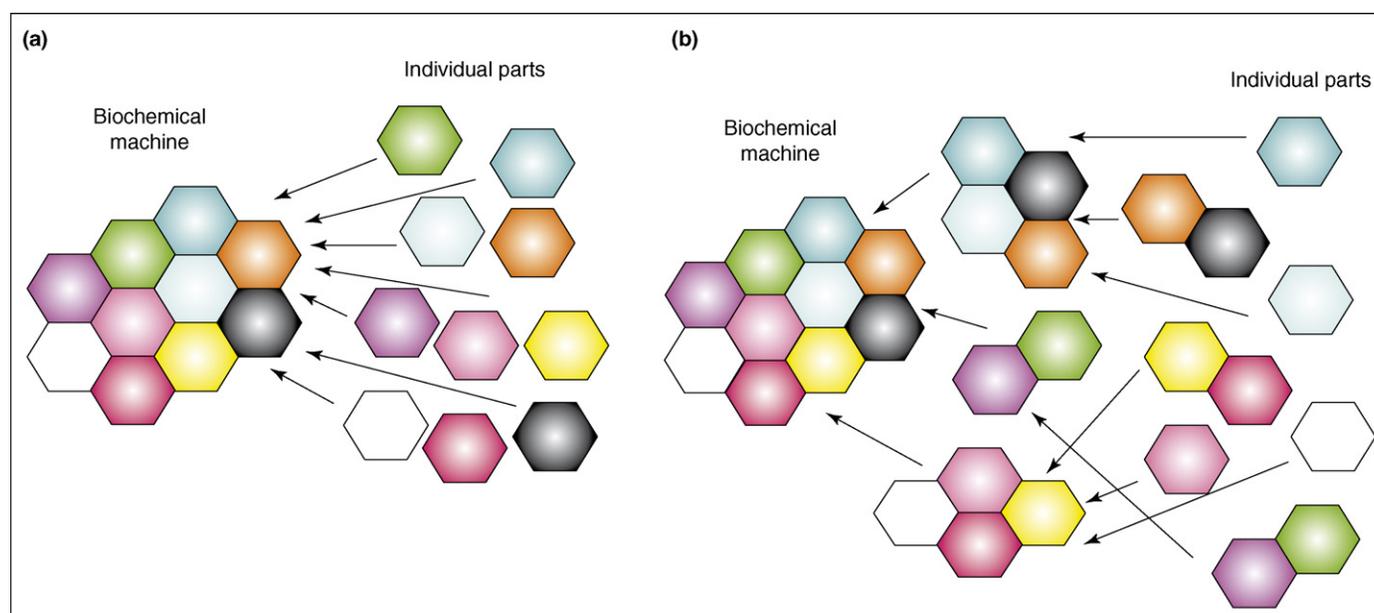


Figure 1. The biochemical argument for intelligent design. (a) Behe's argument for intelligent design at the cellular level depends on 'irreducible complexity' (IC), symbolized here as a biochemical machine made of parts (hexagons), each being essential for function of the whole. Such a machine, he claims, cannot evolve by step-wise Darwinian processes because any precursor lacking a part – which is, therefore, functionless – would fail to be selected (survive). This model predicts that, by themselves, the parts of IC structures have no past or present selectable functions. (b) But the prediction fails. IC objects do exist, yet, as the biochemical literature shows using many examples, their component parts have selectable functions, sometimes independent of the specific function within the 'IC' machine. Thus, IC machines can, and do, evolve as accretions, by step-wise 'Darwinian' means. Their individual components are selectable before assembly into the machine. Reproduced, with permission, from Ref. [92].

history of life that it has been given a new, more carefully chosen name: 'Exaptation. A character previously shaped by selection for a particular role (an adaptation) (...) later co-opted by selection for a new and still current fitness role' [20].

So, it is not true that the individual components of biochemical structures or systems – including Behe's own exemplar, the blood-clotting cascade – have no other function than that which he chooses to associate with the putative IC system. Thrombin, for example, has functions, including one in the complement system, other than its central role in clotting. And these functions are credibly interpreted in terms of the evolutionary history of thrombin [21] (Figure 2). Assignment of a single function to any set, especially a large set, of interacting macromolecules is arbitrary. Indeed, the opposite condition – a dense pleiotropy – has emerged in contemporary, systemic genomics and proteomics, especially among regulatory genes [22]. Beyond the error of proclaiming IC un-evolvable, Behe dismisses the demonstrated frequency, in the history of Earth's biota, of gene and whole-genome duplication events, followed by diversification of structure and, eventually, of 'function' among the copies so produced. But the combination of exaptation and genetic duplication-divergence, for which a mass of evidence exists, makes the IC argument naïve (see later).

Other problems with the 'scientific' scholarship of the ID movement were visible in 1996, for example, when Behe announced that the literature of biochemistry contains no discussion of – and, therefore, no plausible mechanisms for – the evolution of well-known, complex biochemical processes such as adaptive immunity [2]. That claim, which he has not relinquished, was a rallying cry for the rise of ID 'theory' in the 1990s. Bottaro *et al.* have described plaintiffs' attorney Eric Rothschild's confrontation of Behe at the

Dover trial with massive refutation of the claim: a large body of literature on immune-system evolution represented in court by a foot-high stack of actual, peer-reviewed, published material – which Rothschild dramatically set before Behe on the witness stand – the existence of which Behe had ignored or shrugged off [23]. Contained therein was the well-understood origin, first suggested in the late 1970s, of contemporary recombination-activating genes of the vertebrate immune system in an ancient transposase [23]. A detailed review of literature on evolution of the adaptive immune system, specifically in light of the IC argument, has been provided by Inlay [24].

The IC argument for intelligent design of the bacterial flagellum – so gripping for laymen and bloggers, print journalists, and Behe's non-biologist Wedge associates – is put firmly to rest by modern research on origins and homologies among the structural and catalytic proteins of flagellar and bacterial secretory systems. This question has a large and growing literature, the burden of which is that reasonable lines of descent from the latter to the former, or at least from an origin common to both, are evident in contemporary biochemical and ultrastructural detail. There is no good reason to imagine that bacterial flagella appeared on Earth 'in one fell swoop' [25,26].

More recently, in response to criticism of his failure to publish in the primary biochemical literature, Behe offered for the first time a peer-reviewable argument for his questioning of 'Darwinism' (which has in fact become rather half-hearted with his admissions, e.g. that some – not all – proteins have evolved). Behe's aim was to justify his original dismissal of gene duplication – neo-functionalization in system evolution. He and mathematical physicist David W. Snoke constructed a model [27] that offered quantitative argument and calculations to the effect that certain essential functional features of proteins involving

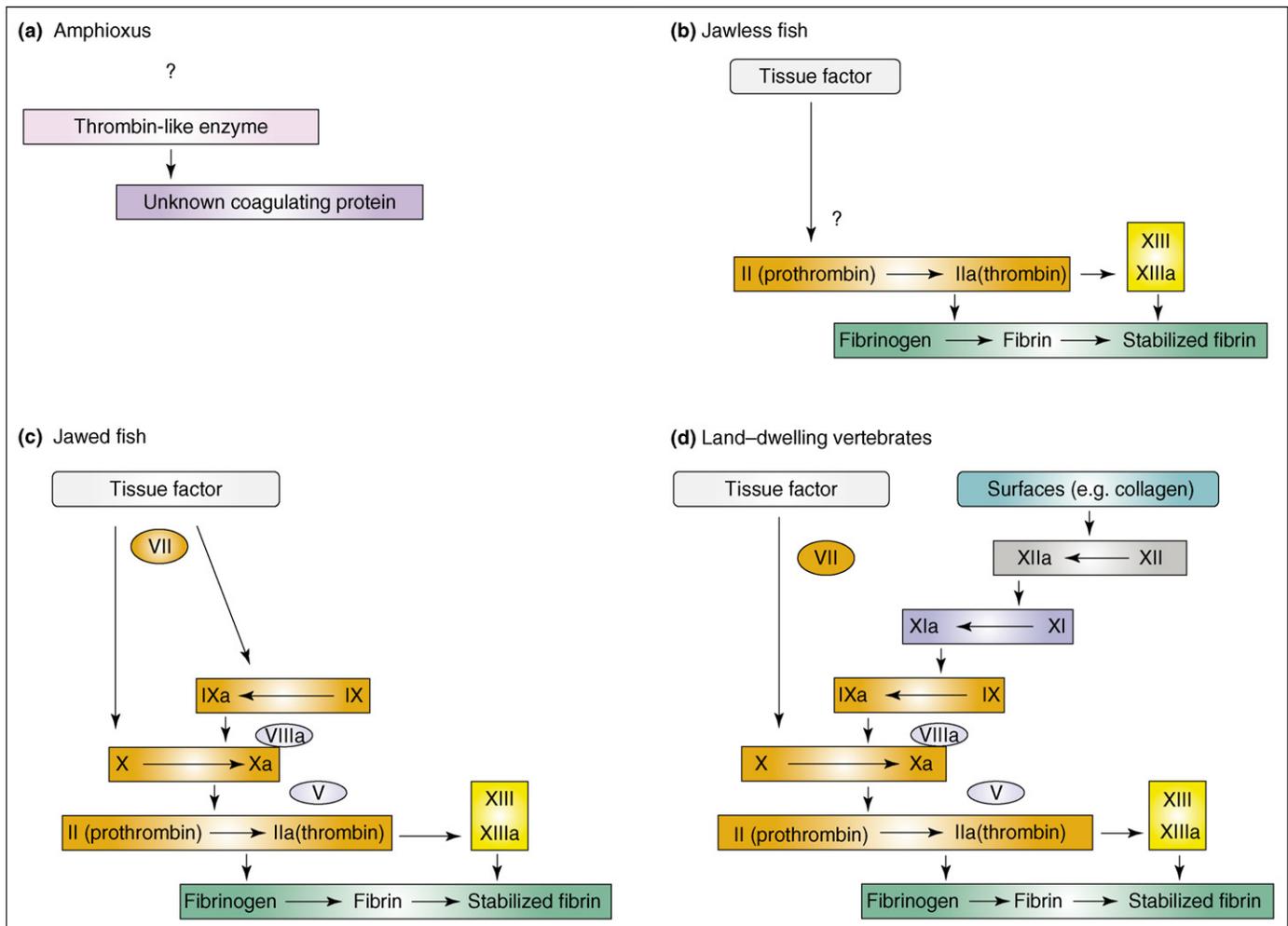


Figure 2. Chordate clotting system. Comparative biochemistry of chordate blood clotting: a matter (contra Behe) of 'reducible' complexity. Clotting cascades are present, from the apparently simple versions in Amphioxus (a) and in the jawless fishes (Agnatha – lampreys and hagfishes) (b), through the intermediate system of jawed fish (c), to the complex and densely interlocked system in the terrestrial vertebrates (d). All of these clotting cascades have molecular members in common, but their complexity is 'reducible' because the contemporary array reflects modifications and additions to the earliest versions – in response to changing environments and the passage of (geological) time. Reproduced, with permission, from Ref. [93].

multiple amino acid residues are extremely unlikely to arise by Darwinian mechanisms.

Behe and Snoke's theoretical, mathematical-computational effort, complex enough in itself, is based upon several simple, formal assumptions about the process. It estimates the probability that, in consequence of point mutations subsequent to a duplication event, a gene will acquire a new multi-residue feature (such as a disulfide bond between two cysteine residues) necessary for a new function. Behe and Snoke make certain highly restrictive assumptions, including the requirement that all mutations contributing to the new structure-function must arise only after the duplication. Their results seem to demonstrate that fixation of new multi-residue features arising via point mutation in duplicate genes would require far too much time or populations far too large: 'we conclude that, in general, to be fixed in 10^8 generations, the production of novel protein features that require the participation of two or more amino acid residues simply by multiple point mutations in duplicated genes would entail population sizes of no less than 10^{99} ' [27]. These results were gratifying to ID activists, who have promoted them energetically.

This article by Behe and Snoke prompted immediate technical objections not only in letters from readers to the editor but also in a full manuscript from mathematical population geneticist Michael Lynch [28]. His calculation of the same probabilities (time or number of generations to fixation of the new feature as a function of population size) is based upon assumptions far more biologically realistic, including full compatibility with the conventional framework of population genetics. Lynch points out that this model is nonetheless 'the closest possible Darwinian version of the Behe and Snoke model in that the intermediate states of protein evolution involve functional products with no immediate positive effects on organismal fitness (the latter consistent with the assumptions of Behe and Snoke)' [28]. (The Behe-Snoke model for evaluating the sufficiency of Darwinian processes is, in fact, non-Darwinian because it specifies functionally neutral intermediates only during the process of change.) In the Lynch report [28], the answers sought are again (i) a realistic frequency of neo-functionalization in duplicate genes and (ii) the time needed for it to occur. However, Lynch's conclusions, with very conservative conditions for the new protein function, are very different from those of Behe-Snoke: time scales of

$<10^6$ years for population sizes $>10^6$. Those are entirely practical numbers in the context of geological time for the haploid, non-recombining bacterial genomes for which both models were constructed.

Protein Science published Behe's short, irenic, but ineffective response to Lynch, in addition to an editorial summarizing the responses of readers. Editor Mark Hermodson noted in his concluding comments that 'Prof. Lynch's approach of testing the problem raised by Drs Behe and Snoke within the modern framework of evolutionary biology represents the desirable scientific approach' [29].

Independently thereof, of course, most biochemists know that proteins have evolved both in nature and in the laboratory. Therefore, interesting as the models mentioned here are, the underlying question of whether proteins evolve is moot. And, so far as sophisticated mathematical and computational models are concerned, they have yielded, in competent hands, solid evidence for an evolutionary origin of the existing protein structure space [30]. More to the point of the IC (and ID) argument are such contributions as the review of research on the origin of new genes prepared by Long *et al.* [31]. These authors have assembled the molecular evidence for gene evolution by the several mechanisms known to operate (i.e. exon shuffling, gene duplication, retroposition, mobile elements, lateral gene transfer, fusion and fission of existing genes, and origination *de novo*). Long and colleagues provide examples of specific genes arising in each mode and examine them [31].

IC is the heart of ID, including the various formal and mathematical claims in its behalf – those of William Dembski, for example, in *No Free Lunch* [32]. It was, and is, a failed argument. Ever stronger empirical evidence thereof continues to appear, even as we write. But even if it were not so obviously failed, there would be no excuse for inserting Behe's kind of argument into primary and secondary school science classes in the US. Even without the obvious failure, such argument is now, at best, a marginal issue for the vast body of solid evolutionary science. The insistence of Behe and his colleagues that their unsubstantiated claims be represented in school science is the giveaway: they are not concerned with the orderly exchanges and progress of science, but with the rapid de-legitimization of evolution.

Behe's co-optation of biochemistry and its repercussions

The fact that competent investigators have taken the time and the trouble to provide solid refutations of Behe's claims does not mean that Behe produced them within a genuinely scientific paradigm or that his respondents regard them as such. To view the ID movement as an effort to offer a scientific explanation whose proponents have tried but simply failed so far to win serious consideration in such disciplines as biochemistry is to take it for something it is not, namely, a good-faith effort to advance scientific knowledge. Although, as the most visible scientist of the movement, Behe highlights the religious framework of ID less prominently in his published work than do his associates, he has done so openly and unambiguously when the need has arisen. For Behe and the other ID leaders, the primary operative concept is not only God but, specifically, the

Christian God [33]. In *Darwin's Black Box*, Behe insists that the argument that science must avoid the supernatural 'is an artificial restriction on science' [2]. Writing for a Christian magazine in 1998, Behe explained why 'scientific evidence of design means a lot for Christians' – ID is both a proselytizing tool and a weapon against the scientific materialism that he believes has so damaged western culture:

First, (...) understanding (...) God's creation allows us to take greater delight in his works (...). Second, Christians live in the world with non-Christians. We want to share the Good News with those who have not yet grasped it, and to defend the faith against attacks. Materialism is (...) a weapon that (...) antagonists use against Christianity and a stumbling block to some who would otherwise enter the church. To the extent that the credibility of materialism is blunted, the task of showing the reasonableness of the faith is made easier. Although Christianity can live with a world where physical evidence of God's action is hard to discern, materialism has a tough time with a universe that reeks of design [34].

In his 2001 'Reply to My Critics' [35], Behe argues that appealing to God to explain biochemical phenomena is scientifically legitimate:

If the designer is a supernatural entity, is intelligent design an 'explanation'? (...) [A] conclusion of intelligent design (...) where the designer is likely to be God is as much an explanation as (...) for cases where the designer is a natural being. (...) Perhaps intelligent design in biochemistry is some sort of an explanation, but is it a 'scientific' explanation if the designer is likely to be God? I contend that it is (...) [35].

Since the early 1990s, when the ID movement began to coalesce under Phillip Johnson's leadership, Behe's use of biochemistry on behalf of ID has been vital to advancing the movement's religious goals, which Johnson candidly revealed in 2003: 'Our strategy has been to change the subject a bit so that we can get the issue of intelligent design, which really means the reality of God, before the academic world and into the schools' [36]. These unmistakable – and, as noted, openly announced – religious aims eventually generated legal repercussions in Behe's home state. In December 2004, 11 parents in Dover (PA, USA) filed a lawsuit (Kitzmiller *et al.* vs Dover Area School District), after the Dover school board adopted a policy requiring that ID be taught as a scientific theory in the local high school. Behe was the primary expert witness for the defense. The defense effort, in the first attempt by ID proponents to escape the fate of earlier attempts to teach creationism in American public schools, failed completely. Realizing that ID 'theory' was the real defendant in the board's shaky case, the Discovery Institute had opposed the policy but failed to persuade the school board to abandon it [37]. Their worst fears were confirmed on 20 December, 2005, when Judge John E. Jones III ruled that ID is creationism, thus a religious belief, and therefore unconstitutional in US public school science classes [5].

Nevertheless, Behe responded to this resounding legal defeat as follows:

On the day after the judge's opinion, December 21, 2005, as before, the cell is run by amazingly complex, functional machinery that in any other context would immediately be recognized as designed. On December 21, 2005, as before, there are no non-design explanations for the molecular machinery of life, only wishful speculations and Just-So stories [38].

For Behe, the ID argument remains scientifically sound despite the verdict and his own Lehigh University colleagues' unequivocal rejection of it [39]. The legal defeat of ID changed nothing in the eyes of its proponents. The Discovery Institute did not interpret the defeat in *Kitzmiller et al. vs Dover Area School District* as a signal that its efforts should cease. Quite the contrary; within a few days, Behe's ID colleague, philosopher and mathematician Dembski, announced that ID remains strong, as evidenced by its international appeal: 'It is therefore naïve to think that this case spells the end of ID, which is rapidly going international and crossing metaphysical and theological boundaries. I now correspond with ID proponents on every continent (save Antarctica)' [40].

In the *Kitzmiller* trial, however, Behe's evasion of the evidential responsibilities of his profession finally caught up with him. During the 11 years since publication of *Darwin's Black Box*, he has traded on his public audience's ignorance of science, making no attempt to reward their support with research results they could present to the school boards whom they petition on behalf of ID. Behe's 1996 affirmation that 'what I'm really eager to do is write grant proposals to do research on (...) intelligent design theory' [1] has never progressed beyond eagerness. His response at an ID conference in 2000 to questions about his work was recorded by a disappointed attendee: 'He was asked what he would do if he had control of all the funding. [His answer was:] keep it himself. And then he did say that he wanted someone else to do research in a laboratory to support his theory. Why wouldn't he want to do his own research?' [1]. Behe has never exercised his right as a member of the American Society for Biochemistry and Molecular Biology to present his ID arguments at the society's annual meeting, announcing in 2001 that 'I just don't think that large scientific meetings are effective forums for presenting these ideas' [1].

After also admitting in 2001 that his definition of IC is flawed and promising 'to repair this defect in future work' [1], he testified under cross-examination on 19 October 2005 that he had produced no revision [41]. Nonetheless, on the very same day he stated that, to be convinced that the vertebrate immune system is the product of evolution, he would require a 'step-by-step, mutation-by-mutation analysis' and a good deal of other 'relevant information' [42]. When asked why he himself has never done such research, he replied, 'I am not confident that the immune system arose through Darwinian processes, and so I do not think that such a study would be fruitful' [42].

Such scientific credibility as he might have hoped to salvage on the witness stand at the *Kitzmiller* trial had been damaged the previous day during attorney

Rothschild's questioning about Behe's definition of scientific theory: [Rothschild] 'But you are clear, under your definition, the definition that sweeps in intelligent design, astrology is also a scientific theory, correct?' [Behe] 'Yes, that's correct. And let me explain [that] under my definition of the word 'theory,' (...) – a sense of the word 'theory' does not include the theory being true (...) [43]. A generous definition, to be sure, but not quite the way modern science sees it. Astrology is clearly – on fully empirical evidence – false. No scientific theory is permanently 'true' in the deductive sense; but a falsified 'theory' such as astrology is no longer a part of science.

ID in America

The ID movement's scientific sterility might leave one marveling that such an impoverished effort could gain the traction it has in the US. One might also marvel that the ID movement continues after not only its deserved legal defeat but also after post-trial setbacks such as the Ohio Board of Education's *Kitzmiller*-inspired abandonment of an ID lesson plan, fearing a lawsuit with a similar outcome [44]. However, wonderment lessens with the recognition that not even Behe and his ID colleagues believe they are promoting a real scientific theory. When addressing their special constituency, conservative Christians, ID proponents remain true to the spirit and goals of their 'Wedge Strategy', a 1998 document outlining their 20-year agenda. Propelled by powerful cultural and political currents, theirs is a religious crusade to 'reverse the stifling dominance of the materialist worldview, and to replace it with a science consonant with Christian and theistic convictions' [45].

Having plagued the US since the 1925 Scopes trial, the reappearance of creationism as 'intelligent design' reflects the legal, cultural and political developments of the past 20 years (Table 1). Legally, the *Kitzmiller* trial was another in a series of losses that creationists have suffered in federal courts. The ID movement arose in the wake of the 1987 landmark decision of the US Supreme Court (*Edwards vs Aguillard*), which barred the teaching of creationism in US public schools, thus forcing the 1980s 'progressive creationism' to refashion itself as 'intelligent design theory' [46,47]. The increasing religious and political conservatism of Americans since the early 1980s has resulted in declining membership in mainstream religious denominations, whereas evangelical churches have grown [48–50]. By adopting an aggressive political agenda, evangelicals have forged (sometimes uneasy) alliances with conservative Catholics and ultra-orthodox Jews to advance shared cultural and political goals [51,52]. This conservatism, coupled with generally declining science literacy [53], has created a receptive audience for the 'teach the controversy' campaign of the ID movement. This clever marketing ploy, appealing to the willingness of Americans to give all sides of an issue a fair hearing, paints ID as a scientific alternative to evolution in a (fictitious) debate among mainstream scientists about the status of evolutionary theory [54].

Ultimately, the goals of ID creationists stretch far beyond the classroom. They seek to discard Enlightenment principles which, adopted in America by intellectual founders such as Thomas Jefferson and Benjamin Franklin,

formed the basis of American government and science [55]. The ID movement's antipathy to the Enlightenment is understandable: critical inquiry, the central legacy of the Enlightenment, threatens the pre-modern intellectual and religious authoritarianism that the creationists would reinstate. Their attack on science – and eventually on other academic disciplines – is the vehicle for attacking Enlightenment rationalism, as Dembski makes clear:

The question posed by intelligent design is not how we should do science and theology in light of the triumph of Enlightenment rationalism and scientific naturalism. The question is rather how we should do science and theology in light of the impending collapse of Enlightenment rationalism and scientific naturalism. These ideologies are on the way out (...) because they are bankrupt (...) [56]. The scientific picture of the world championed since the Enlightenment is (...) massively wrong. Indeed, entire fields of inquiry (...) will need to be rethought from the ground up in terms of intelligent design [57].

ID abroad

As Dembski indicated in the wake of the Kitzmiller loss, ID is indeed 'going international'. The movement's domestic setbacks have energized its cultivation of international support. Fortunately, a 2005 study of attitudes towards evolution in the US, Europe and Japan produced hopeful results for the latter two populations. Whereas only Turkey outranks the US in the number of adults rejecting evolution, comfortable majorities support it in most European countries and Japan. (This study reported that 39% of Americans reject evolution, with 21% unsure. Accompanying data shows that, among Turkish adults (numerical figures are not given) slightly more than 50% reject evolution, with just under 25% unsure [53].) However, lest Europeans feel safely immune to the advance of creationism, they should heed recent developments on the continent and elsewhere [58].

Trading on the global rise of religious fundamentalism, these developments seem to be the work of indigenous European creationists in addition to efforts by Americans, including ID proponents, to export America's 'culture war'. The Discovery Institute is attempting fairly aggressively to cultivate a European following. If developments abroad mirror the US trend, old-earth and young-earth creationists will combine forces, despite their doctrinal differences, to make a greater impact. Discovery Institute fellow and young-earth creationist Paul Nelson recently lectured about ID in Norway [59]. During the Kitzmiller trial, Discovery Institute creationists held an ID conference in Prague, winning no mainstream scientific support but generating some publicity in the Czech media, publicity being the movement's lifeblood [60].

ID seems to be generating the most interest, however, in the UK. The British government has ceded control of several publicly financed secondary schools to creationists in return for contributions from wealthy donors of 10% towards the start-up costs of the schools. With the endorsement of the Blair administration, these schools are now teaching creationism [61,62]. Stephen Layfield, the Head

of Science at Emmanuel College (Gateshead, Tyne and Wear, UK; www.emmanuelctc.org.uk), the most well-known of such schools, recommended *Darwin's Black Box* as 'essential background reading' in a lecture at the school on 'The Teaching of Science' in 2000 [63]. In October–November 2004, ID leader Phillip Johnson toured 11 UK cities with British young-earth creationist Andrew Snelling, reportedly addressing ~8 000 people [64,65].

The Royal Society (www.royalsoc.ac.uk) has seen fit to address publicly the issue of creationism in the UK, where a British creationist group is providing ID videos to schools [66–68]. In late 2006, DVDs featuring Discovery Institute creationists were sent to the science department of every secondary school in England by Truth in Science, a British pro-ID organization, which reports that 59 schools are using them as teaching resources [68]. The Truth in Science website (www.truthinscience.org.uk) offers teachers an ID lesson plan about irreducible complexity and a teachers' manual specifying that students must 'know that Dr Michael Behe is an example of a scientist who questions whether Darwin's theory can account for the complexity of the cell' [69,70].

No country is exempt from creationist encroachments. One in three Swiss consider evolution 'definitely false' [71]. Warnings are sounding from Germany, where creationism has penetrated academia with help from microbiologist and young-earth creationist Siegfried Scherer, a Discovery Institute fellow from 2000–2003 [72–74]. Perhaps encouraged by President Bush's support for teaching ID in America, the Australian education minister supports teaching it in Australian science classes [75]. Bishop Boniface Adoyo, head of Kenya's National Evangelical Alliance, demands that the National Museum of Kenya hide its fossils from view by young Africans [76].

Nature recently featured a 'special report' cataloging problems with creationism in western Europe, Turkey and Russia [10]. Turkey harbors a particularly active network of creationists, one of whom – Mustafa Akyol – is a prominent Discovery Institute ally, appearing publicly in America with ID supporter and spokesman Denyse O'Leary. (O'Leary is a Canadian journalist with no scientific background, who typifies the ID movement's support base [77–80].) Unsettling signals are coming even from the Vatican, where Cardinal Christoph Schönborn's July 2005 public statement of support for ID, released by the public relations firm of the Discovery Institute, was followed by ambiguous comments from Pope Benedict [81]. Statements from the pope released in April 2007 have not dispelled concerns about this ambiguity [82,83].

Future perspectives: lessons from America

America's experience should be instructive to scientists and the concerned lay public abroad. In the short term, creationism threatens the already weak public understanding of basic science, thus posing a corresponding, immediate threat to proper science education. In the longer term, once the public understanding of science is sufficiently degraded, the degrading of public support for scientific research could well follow. One Discovery Institute creationist has urged American ID supporters to lobby their elected officials for a reduction in the funding of

evolution-related research [6]. Because there is a direct connection between the public understanding of science and public support for scientific research, the actual practice of science is thus threatened by a loss of such support. Moreover, the assault on science is accompanied by regressive social attitudes such as religious exclusionism and opposition to secular government [33,55].

The ID contingent of the Discovery Institute has suffered additional, major defeats since the Kitzmiller trial, but even if their Wedge Strategy ultimately fails, past experience indicates that a new generation of ID supporters will follow in their wake. If there is a single most important lesson for scientists and concerned citizens, it is that creationists never give up. They merely change their strategy with each defeat, necessitating corresponding adjustments and constant vigilance by their opponents. Although they might not enjoy widespread public support abroad, committed creationists can produce effects disproportionate to their numbers. Devoted full-time to their calling, buoyed by favorable political winds and government contacts, a handful of creationists can leave wreckage in their wake even when they lose, as the citizens of tiny Dover (PA, USA) have discovered. More than a year after the trial, they are still cleaning up the mess.

References

- Forrest, B. and Gross, P.R. (2007) *Creationism's Trojan Horse: The Wedge of Intelligent Design*. (2nd edn), Oxford University Press
- Behe, M.J. (1996) *Darwin's Black Box: The Biochemical Challenge to Evolution*. Simon & Schuster
- Geisler, N.L. (1982) Record of defense's science testimonies. In *Creator in the Courtroom: Scopes II*, pp. 139–161, Mott Media
- Behe, M.J. (1996) Evidence for intelligent design from biochemistry: From a speech delivered at Discovery Institute's God & Culture conference, 10 August (<http://web.archive.org/web/19961102121426/www.discovery.org/behespch.html>)
- Kitzmiller *et al.* vs Dover Area School District (2005) Memorandum Opinion, 20 December, pp. 1–139 (http://www.pamd.uscourts.gov/kitzmiller/kitzmiller_342.pdf)
- Wells, J. (2000) *Icons of Evolution: Science or Myth? Why Much of What We Teach About Evolution Is Wrong*. Regnery
- Richards, J.W. and Gonzalez, G. (2004) *The Privileged Planet: How Our Place in the Cosmos is Designed for Discovery*. Regnery
- Johnson, P.E. (2001) The Wedge: a progress report. *Phillip Johnson's Weekly Wedge Update*, 16 April (http://www.arn.org/docs/pjweekly/pj_wedgeprogress041601.htm)
- Weikart, R. (2004) *From Darwin to Hitler: Evolutionary Ethics, Eugenics, and Racism in Germany*. Palgrave Macmillan
- Graebisch, A. and Schiermeier, Q. (2006) Anti-evolutionists raise their profile in Europe. *Nat.* 44, 406–407
- Center for the Renewal of Science and Culture (1996) Michael Behe (<http://web.archive.org/web/19961102121407/www.discovery.org/behe.html>)
- Center for Science and Culture (2006) Michael J. Behe, Senior Fellow (<http://www.discovery.org/scripts/viewDB/index.php?command=view&id=31&isFellow=true>)
- Dunkelberg, P. (2003) Irreducible complexity demystified. *Talkdesign.org* 26 April (<http://www.talkdesign.org/faqs/icdmyst/ICdmyst.html>)
- Gross, P.R. (1996) The dissent of man. *Wall St. J.* 30 July, p. A12
- Variou (2006) Behe, Michael (<http://www.talkreason.org/evolinks/eng/antievolution/persons/MichaelBehe/index.html>)
- Dembski, W.A. (2004) Irreducible complexity revisited. *PCID* November (http://www.iscid.org/pcid/2004/3/1/dembski_ic_revisited.php)
- Muller, H.J. (1918) Genetic variability, twin hybrids and constant hybrids, in a case of balanced lethal factors. *Genetics* 3, 422–499
- Muller, H.J. (1939) Reversibility in evolution considered from the standpoint of genetics. *Biol. Rev.* 14, 261–280
- Theobald, D. (2006) The Mullerian two-step: add a part, make it necessary, or why Behe's 'Irreducible Complexity' is silly. 21 November (<http://www.talkorigins.org/faqs/comdesc/ICsilly.html>)
- Vrba, E.S. (2002) Exaptation. In *Encyclopedia of Evolution* (Vol. 1) (Pagel, M., ed.), In pp. 338–339, Oxford University Press
- Huber-Lang, M. *et al.* (2006) Generation of C5a in the absence of C3: a new complement activation pathway. *Nat. Med.* 12, 682–687
- Hittinger, C.T. *et al.* (2005) Pleiotropic functions of a conserved insect-specific Hox peptide motif. *Development* 132, 5261–5270
- Bottaro, A. *et al.* (2006) Immunology in the spotlight at the Dover 'Intelligent Design' trial. *Nat. Immunol.* 7, 433–435
- Inlay, M. (2002) Evolving immunity: A response to chapter 6 of *Darwin's Black Box*. 17 July (http://www.talkdesign.org/faqs/Evolving_Immunity.html)
- Pallen, M.J. and Matzke, N.J. (2006) From *The Origin of Species* to the origin of bacterial flagella. *Nat. Rev. Microbiol.* 4, 784–790
- Zimmer, C. (2006) From fins to wings. *Nat. Geogr.* November 210, 111–128
- Behe, M.J. and Snoke, D.W. (2004) Simulating evolution by gene duplication of protein features that require multiple amino acid residues. *Protein Sci.* 13, 2651–2664
- Lynch, M. (2005) Simple evolutionary pathways to complex proteins. *Protein Sci.* 14, 2217–2225
- Hermoldson, M. (2005) Editorial and position papers. *Protein Sci.* 14, 2215–2216
- In-Geol, Choi and Sung-Hou, Kim (2006) Evolution of protein structural classes and protein sequence families. *Proc. Natl. Acad. Sci. U. S. A.* 103, 14056–14061
- Long, M. *et al.* (2003) The origin of new genes: glimpses from the young and old. *Nat. Rev. Genet.* 4, 865–875
- Dembski, W.A. (2001) *No Free Lunch: Why Specified Complexity Cannot Be Purchased Without Intelligence*. Rowman and Littlefield
- Forrest, B. The non-epistemology of intelligent design: Its implications for public policy. *Synthese* (in press)
- Behe, M.J. (1998) Tulips and dandelions. *Books and Culture: A Christian Review*. September–October (<http://web.archive.org/web/20001208124700/http://www.christianitytoday.com/bc/8b5/8b5034.html>)
- Behe, M.J. (2001) Reply to my critics: a response to reviews of *Darwin's Black Box: The Biochemical Challenge to Evolution*. *Biol. Philos.* 16, 685–709
- Johnson, P.E. (2003) American Family Radio, 10 January. In Claim C1001.1: Intelligent design (ID) is scientific, not religious (http://www.talkorigins.org/indexcc/CI/CI001_1.html)
- Kauffman, C. (2005) Intelligent designers down on Dover. *York Dispatch* 23 September (http://www.yorkdispatch.com/local/ci_3042920)
- Behe, M.J. (2006) Whether intelligent design is science: a response to the opinion of the court in *Kitzmiller vs Dover Area School District*, 1–12 (<http://www.discovery.org/scripts/viewDB/filesDB-download.php?command=download&id=697>)
- Lehigh University Dept. of Biological Sciences. (2005) Department position on evolution and 'Intelligent Design' (<http://www.lehigh.edu/~inbios/news/evolution.htm>)
- Dembski, W.A. (2006) Life after Dover. *Sci. & Theology News* 2
- Kitzmiller, *et al.* vs Dover Area School District. (2005) Transcript of proceedings. Morning session, 19 October (http://www2.ncseweb.org/kvd/trans/2005_1019_day12_am.pdf)
- Kitzmiller, *et al.* vs Dover Area School District. (2005) Transcript of proceedings. Afternoon session, 19 October (http://www2.ncseweb.org/kvd/trans/2005_1019_day12_pm.pdf)
- Kitzmiller, *et al.* vs Dover Area School District. (2005) Transcript of proceedings. Afternoon session, 18 October (http://www2.ncseweb.org/kvd/trans/2005_1018_day11_pm.pdf)
- National Center for Science Education (2006) More on the Ohio victory. 17 February (http://www.ncseweb.org/resources/news/2006/OH/15_more_on_the_ohio_victory_2_17_2006.asp)
- Center for the Renewal of Science and Culture (1998) The wedge (<http://www.seattleweekly.com/news/0605/discovery-wedge.php>)
- Forrest, B. (2005) Expert witness report. *Kitzmiller et al. vs Dover Area School District* (http://www2.ncseweb.org/wp/?page_id=12)
- Scott, E.C. (2004) Neocreationism. In *Evolution vs. Creationism: An Introduction*, pp. 113–133, Greenwood Press

- 48 Demerath, N.J., III (1995) Cultural victory and organizational defeat in the paradoxical decline of liberal Protestantism. *J. Sci. Study Relig.* 34, 458–469
- 49 Cho, D. (2002) Evangelicals help pace U.S. growth in church attendance. *Wash. Post* 17 September, p. A03
- 50 Kohut, A. et al. (2000) American religion at the close of the twentieth century. In *The Diminishing Divide: Religion's Changing Role in American Politics*, pp. 16–33, Brookings Institution Press
- 51 George, R.P. (2000) What can we reasonably hope for? *First Things* 99, 22–24 In: http://www.firstthings.com/article.php3?id_article=2506
- 52 Bendyna, M.E. et al. (2001) Uneasy alliance: conservative Catholics and the Christian right. *Sociol. Relig.* 62, 51–64
- 53 Miller, J.D. et al. (2006) Public acceptance of evolution. *Sci.* 313, 765–766
- 54 Shaw, L. (2005) Does Seattle group 'teach controversy' or contribute to it? *Seattle Times* 31 March (http://seattletimes.nwsource.com/html/localnews/200225932_design31m.html)
- 55 Forrest, B. and Gross, P.R. (2005) The wedge of intelligent design: retrograde science, schooling and society. In *Scientific Values and Civic Virtues* (Koertge, N., ed.), pp. 191–214, Oxford University Press
- 56 Dembski, W.A. (1999) Preface. In *Intelligent Design: The Bridge Between Science and Theology*, pp. 14–15, InterVarsity Press
- 57 Dembski, W.A. (1999) The act of creation. In *Intelligent Design: The Bridge Between Science and Theology*, p. 224, InterVarsity Press
- 58 *The Economist*. (2007) In the beginning. 19 April (http://www.economist.com/world/displaystory.cfm?story_id=9036706)
- 59 Bryne, S. (2006) Hadde Darwin rett? *Dagbladet* 22 September (<http://www.dagbladet.no/nyheter/2006/09/20/477320.html>)
- 60 Kononczuk, P. (2005) Scientist presents his controversial theory of intelligent creator. *Prague Post* 19 October (<http://www.praguepost.com/articles/2005/10/19/daring-to-challenge-darwin.php>)
- 61 British Humanist Association (2004) BHA briefing 2004/6: creationist academics 6 June (<http://www.humanism.org.uk/site/cms/contentViewArticle.asp?article=1687>)
- 62 British Humanist Association (n.d.) Creationism in British schools (<http://www.humanism.org.uk/site/cms/contentviewarticle.asp?article=1191>)
- 63 Layfield, S. (2000) The teaching of science: a biblical perspective. *The Christian Institute* 21 September (<http://web.archive.org/web/20010505063326/http://www.christian.org.uk/html-publications/education3.htm>)
- 64 Johnson-Snelling 2004 tour dates and venues (2004) Darwin Reconsidered (http://www.darwinreconsidered.org/tour_dates_venues.asp)
- 65 News from the tour (2004) Darwin Reconsidered (<http://www.darwinreconsidered.org/tournews.asp>)
- 66 Royal Society (2006) Royal Society statement on evolution, creationism and intelligent design, 11 April (<http://www.royalsoc.ac.uk/news.asp?year=&id=4298>)
- 67 Jones, S. (2006) Why creationism is wrong and evolution is right (Royal Society public lecture), 11 April (<http://www.royalsoc.ac.uk/event.asp?id=4140>)
- 68 Randerson, J. (2006) Revealed: rise of creationism in UK schools. *Educ. Guardian* 27 November (<http://education.guardian.co.uk/schools/story/0,1957858,00.html>)
- 69 Truth in Science (n.d.) How science works: Irreducible complexity – teachers' notes (http://www.truthinscience.org.uk/site/custom/Irreducible_Complexity_Lesson_Plan.pdf)
- 70 Truth in Science (2006) *Where Does the Evidence Lead? Teachers Manual* (http://www.truthinscience.org.uk/site/custom/TiS_Pack_Teachers_Manual.pdf)
- 71 Stephens, T. (2006) Swiss drag knuckles accepting evolution. *Swiss Info* 9 October (http://www.swissinfo.org/eng/feature/detail/Swiss_drag_knuckles_accepting_evolution.html?siteSect=108&sid=7141596&cKey=1160375999000)
- 72 Kutschera, U. (2003) Darwinism and intelligent design: the new anti-evolutionism spreads in Europe. *Rep. of the Natl. Cent. for Sci. Educ.* 23, 17–18
- 73 Discovery Institute, Center for the Renewal of Science and Culture. (2000) Fellow Siegfried Scherer (<http://web.archive.org/web/20000818193424/www.discovery.org/crsc/fellows/SiegfriedSchere/index.html>)
- 74 Discovery Institute, Center for Science and Culture. (2003) Fellow Siegfried Scherer (<http://web.archive.org/web/20030624014533/www.discovery.org/crsc/fellows/SiegfriedSchere/index.html>)
- 75 Wroe, D. (2005) 'Intelligent design' an option: Nelson. *The Age* (Melbourne, Australia) 11 August (<http://www.theage.com.au/articles/2005/08/10/1123353386917.html>)
- 76 McKie, R. (2006) Kenya bishop leads anti-evolution fight. *Guardian Observer* 10 September (<http://observer.guardian.co.uk/world/story/0,1868904,00.html>)
- 77 Heneghan, T. (2006) Creation vs Darwin takes Muslim twist in Turkey. *Reuters* 22 November (<http://www.wrn.org/article.php?idd=23461&sec=33&con=54>)
- 78 MacLaurin Institute (2006) International journalists question media treatment of intelligent design. (Press release) 20 October (http://maclaurin.org/pressreleases.php?pr_id=120)
- 79 O'Leary, D. (2006) Post details: Part one: how I got involved in covering the intelligent design controversy as a regular beat. *ID Report*, 5 October (http://www.arn.org/blogs/index.php/2/2006/10/05/1stronglegmpart_one_1_emghow_i_got_invo)
- 80 Dembski, W.A. and O'Leary, D., eds (2006) *Uncommon Descent: The Intelligent Design Weblog of William Dembski, Denyse O'Leary & Friends*, In: <http://www.uncommondescent.com/>
- 81 Peretó, J. (2006) Intelligent design and the assault on science. *Eurozine* 13 July (<http://www.eurozine.com/articles/2006-07-13-pereto-en.html>)
- 82 Lawton, M. (2007) In new book, pope quoted as seeing no conflict between faith, science. *Catholic News Service* 13 April (<http://www.catholicnews.com/data/stories/cns/0702071.htm>)
- 83 Owen, R. (2007) Pope puts his faith in the Book of Genesis, not Darwin. *The Times (Lond.)* 13 April (<http://www.timesonline.co.uk/tol/news/world/europe/article1647614.ece>)
- 84 National Public Radio (2005) Timeline: remembering the Scopes monkey trial. 5 July (<http://www.npr.org/templates/story/story.php?storyId=4723956>)
- 85 McLean vs Arkansas Documentation Project. (2005) (http://www.antievolution.org/projects/mclean/new_site/index.htm)
- 86 Thaxton, C.B. et al. (1984) *The Mystery of Life's Origin: Reassessing Current Theories*. Lewis and Stanley
- 87 Edwards v.s. Aguillard. (1987) U.S. Supreme Court (http://supct.law.cornell.edu/supct/html/historics/USSC_CR_0482_0578_ZO.html)
- 88 Witham, L.A. (2002) *Where Darwin Meets the Bible*. Oxford University Press
- 89 Johnson, P.E. (1991) *Darwin on Trial*. Regnery Gateway
- 90 Miller, K.R. (1999) *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution..* Cliff Street Books
- 91 Holloway, A. (2005) Elim-backed antievolution tour fills churches as law professor and geologist unite against the theory. *Direction Magazine* January (<http://www.darwinreconsidered.org/media/p18-23Screen.pdf>)
- 92 Miller, K.R. (2003) Answering the biochemical argument from design. In *God and Design: The Teleological Argument and Modern Science* (Manson, N.A., ed.), pp. 292–307, Routledge
- 93 Musgrave, I. (2006) The politically incorrect guide to Darwinism and intelligent design review: IC is not nice (chapter 10). *Pandasthumb.org* 8 September (http://www.pandasthumb.org/archives/2006/09/the_politically_10.html)
- 94 Darwin, C. (1859) *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. John Murray, (Albemarle Street, London In: <http://www.esp.org/books/darwin/origin/facsimile/>)