

Federal Rule of Civil Procedure 26 Disclosure of Expert Testimony

of

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1) My qualifications as an expert witness:

PROFESSIONAL EXPERIENCE

9/97-present	Professor of Biological Sciences, Lehigh University
1996-present	Fellow, Discovery Institute's Center for Science and Culture
6/95-8/97	Associate Professor of Biological Sciences, Lehigh University
9/85-6/95	Associate Professor of Chemistry, Lehigh University
7/89-12/89	Visiting Associate Professor of Biochemistry, Hershey Medical Center/Penn State
9/82-8/85	Assistant Professor of Chemistry, City University of New York, Queens College
11/78-9/82	Jane Coffin Childs Fund Postdoctoral Fellow at the National Institutes of Health (Gary Felsenfeld, advisor)
9/74-10/78	National Research Service Award Predoctoral Fellow at the University of Pennsylvania (Walter Englander, mentor)

EDUCATION

Ph. D.	Biochemistry, 1978. University of Pennsylvania, Philadelphia, Pennsylvania.
B.S.	Chemistry, 1974. Drexel University, Philadelphia, Pennsylvania.

PUBLICATIONS IN THE LAST TEN YEARS

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2) The compensation I will receive for my study, case preparation, and testimony in this matter is \$100.00 per hour. All travel expenses will be billed at cost.

3) I have not testified as an expert at trial or by deposition within the preceding four years.

- 4) The following includes a complete statement of my opinions to be expressed, the reasons and basis underlying them, the data and other information considered in forming them, and exhibits.

List of Exhibits

- Exhibit 1 — Abstracts from PubMed which contain the word "theory"
- Exhibit 2 — A drawing of the bacterial flagellum from a biochemistry textbook
- Exhibit 3 — Cover page and Table of Contents of the February 6, 1998 issue of the journal *Cell*
- Exhibit 4 — *New York Times* op-ed summarizing the argument for intelligent design
- Exhibit 5 — "Directed Panspermia" by Francis Crick and Leslie Orgel
- Exhibit 6 — *New York Times* article "Biology Text Illustrations More Fiction Than Fact" (sidebar)
- Exhibit 7 — *Philosophy of Science* journal article
- Exhibit 8 — *Biology and Philosophy* journal article
- Exhibit 9 — My chapter from *Debating Design: From Darwin to DNA* (Oxford University Press)
- Exhibit 10 — *Protein Science* journal article
- Exhibit 11 — journal article on "evolutionary potential" by Barry Hall
- Exhibit 12 — *New York Times* op-ed containing my views on teaching the problems of Darwinian theory

- 1 Intelligent Design as a Scientific Theory
- 1.1 How the word “theory” is used in the scientific community
- 1.1.1 “Theory” as a “well-substantiated explanation”

In both common parlance and scientific practice the word “theory” has several meanings¹. The word “theory” is sometimes used in science to indicate, in the words of the National Academy of Sciences, “a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences and tested hypotheses.”² It is important to remember, however, that even when used in the sense of “well-substantiated” a “theory” is not necessarily either complete or correct. For example, Newton’s theory of motion and gravity was superseded by Einstein’s theory of relativity.³ Newton’s theory had been “well-substantiated” for centuries for bodies of medium size moving at medium speeds (such as cannonballs flying through the air), but did not fit well with bodies moving at very fast velocities, near the speed of light. Another example is the ether theory of the propagation of light, which the eminent 19th century physicist James Clerk Maxwell confidently supported because he thought his equations for electromagnetism required it. The theory proved to be entirely wrong — physicists no longer believe there is such an entity as the “ether”.⁴ Thus, as the history of science richly shows, even a “well-substantiated” theory can later be shown to be incomplete or incorrect.

- 1.1.2 “Theory” as a word that applies to a limited area of science that may be wrong

The word “theory” is also used in scientific practice to apply to proposed explanations that are neither broad in scope nor well-substantiated, which deal with quite limited phenomena that have varying amounts of evidence in their favor, which sometimes are weak or even counterindicated by the data. For example, a search of the online biological database PubMed (which is maintained by the National Library of Medicine, a division of the United States National Institutes of Health) for the word “theory” in abstracts of scientific articles published during or after the year 2000 shows the word is used in varying ways. One article in the *Journal of Theoretical Biology* states that “The membrane pacemaker theory of aging is an extension of the oxidative stress theory of aging.”⁵ A paper in the *Journal of Urology* states that “This study does not support the previous theory that urethral sphincter overactivity ... leads to work hyperplasia...”⁶ A paper in the journal *Breast Cancer Research* states their results “do not support the estrogen hypothesis as a unifying theory for the influence of this period.”⁷ The point is that the word “theory” is used to indicate a wide range of ideas, some supported by results but limited in scope, some contradicted by results.

Ten abstracts of articles found in the PubMed database are included as Exhibit 1. In each, I have circled the word “theory” in red.

- 1.1.3 “Theory” applied to each of rival explanations

The word “theory” is also sometimes used in science for each of the opposing explanations which seek to account for the same set of facts. For example, speaking of the continuing

lack of an accepted Darwinian account of the origin of sexual reproduction (which I discuss at more length in section 3.3) an article in the journal *Science* remarked, "Biologists have come up with a profusion of theories since first posing these questions a century ago."⁸ Notice that the word "theories" is used here to indicate competing explanations. Another, more pertinent example is "complexity theory" in biology, which posits that some complex systems can self-organize. Complexity theory has been proposed as an explanation for the origin of such disparate systems as cellular metabolic pathways and the number of different cell types which an organism contains. A leading complexity theorist, Dr. Stuart Kauffman of the University of Calgary, specifically sees aspects of complexity theory as rival explanations to Darwinian theory. In his book *Origins of Order: Self-Organization and Selection in Evolution* (Oxford University Press, 1993) Kauffman wrote:

Darwin and evolutionism stand astride us, whatever the mutterings of creation scientists. But is the view right? Better, is it adequate? I believe it is not. It is not that Darwin is wrong, but that he got hold of only part of the truth. For Darwin's answer to the sources of the order we see all around us is overwhelmingly an appeal to a single singular force: natural selection. It is this single-force view which I believe to be inadequate, for it fails to notice, fails to stress, fails to incorporate the possibility that simple and complex systems exhibit order spontaneously.⁹

Kauffman and other complexity theorists defend their view against both intelligent design theory and Darwinian theory in the recently published book *Debating Design: From Darwin to DNA* (Cambridge University Press, 2004). Thus in scientific usage different "theories" can be rival explanations for the same data.

1.1.4 "Theory" as a singular word applied to a body of multiple, distinct claims

It is critical to realize that in science the word "theory", in the singular, may be applied to a body of multiple, logically-separable claims, some of which may turn out to be true and others false, which can vary widely in the strength of the evidence supporting them and the ease with which they can be tested. In his book *One Long Argument*, in a chapter entitled "Ideological Opposition to Darwin's Five Theories", the eminent, recently-deceased Harvard biologist Ernst Mayr, one of the founders of the "neo-Darwinian synthesis" in the middle of the 20th century, stressed that what is commonly called "Darwin's Theory" actually contains at least five distinct claims.

In both scholarly and popular literature one frequently finds references to "Darwin's theory of evolution," as though it were a unitary entity. In reality, Darwin's "theory" of evolution was a whole bundle of theories, and it is impossible to discuss Darwin's evolutionary thought constructively if one does not distinguish its various components. The current literature can easily leave one perplexed over the disagreements and outright contradictions among Darwin specialists, until one realizes that to a large extent these differences of opinion are due to a failure of some of these students of Darwin to appreciate the complexity of his paradigm.¹⁰

Mayr lists those five separate claims as:

- (1) *Evolution as such.* This is the theory that the world is not constant nor recently created nor perpetually cycling but rather is steadily changing and that organisms are transformed in time.
- (2) *Common descent.* This is the theory that every group of organisms descended from a

- common ancestor and that all groups of organisms, including animals, plants, and microorganisms, ultimately go back to a single origin of life on earth.
- (3) *Multiplication of species.* This theory explains the origin of the enormous organic diversity. It postulates that species multiply, either by splitting into daughter species or by "budding," that is, by the establishment of geographically isolated founder populations that evolve into new species.
 - (4) *Gradualism.* According to this theory, evolutionary change takes place through the gradual change of populations and not by the sudden (saltational) production of new individuals that represent a new type.
 - (5) *Natural selection.* According to this theory, evolutionary change comes about through the abundant production of genetic variation in every generation. The relatively few individuals who survive, owing to a particularly well-adapted combination of inheritable characters, give rise to the next generation.¹¹

The strength of evidence showing that, say, "the world is not constant" (the first claim) is disputed by virtually no one. On the other hand, the strength of evidence showing that natural selection is the sole or principle mechanism of that change in all cases (the fifth claim) is much weaker — necessarily so, since one has to recognize that change has occurred before one attempts to explain what has caused the change. Mayr writes that in the years after Darwin published his theory, although most scientists accepted change in the world and common descent, few scientists thought that the mechanism of natural selection was convincing, as shown in the table below reproduced from Mayr's book.

TABLE 1¹²
The composition of the evolutionary theories of various evolutionists. All these authors accepted a fifth component, that of evolution as opposed to a constant, unchanging world.

	Common descent	Multiplication of species	Gradu- alism	Natural selection
Lamarck	No	No	Yes	No
Darwin	Yes	Yes	Yes	Yes
Haeckel	Yes	?	Yes	In part
Neo- Lamarckians	Yes	Yes	Yes	No
T. H. Huxley	Yes	No	No	(No) ^a
de Vries	Yes	No	No	No
T. H. Morgan	Yes	No	(No) ^a	Unimportant

a. Parentheses indicate ambivalence or contradiction.

In terms of the various usages of the word "theory" discussed in section 1.1, the Darwinian claim that change has occurred on the earth is "well-substantiated". On the other hand, *the altogether separate Darwinian claim that natural selection drove all the major changes on earth, or built all the complex biochemical and cellular systems, is a "theory" in the much weaker sense of a "hypothesis" or "proposed explanation", with much less hard evidence in its favor.*

1.2 How intelligent design theory fits the definition of a scientific theory

1.2.1 The basic claim of intelligent design theory

Intelligent design (ID) theory proposes that the origin of some aspects of living organisms is best explained as the result of deliberate intelligent design, rather than as the result of such unintelligent processes as the self-organization proposed by complexity theory or the natural selection proposed by Darwinian theory. As such, it is crucial to keep in mind that, much like complexity theory, **intelligent design theory focuses exclusively on the proposed mechanism of how complex biological structures arose**. In other words, **ID focuses exclusively on the fifth claim of Darwinism (Natural selection) in Ernst Mayr's list on the preceding page**, and does not concern any of the other claims.

No matter what some people in the general public may say or hope, ID theory does not concern the age of the earth or common descent or any other claims of Darwinian theory except its proposed mechanism. Rather, ID theory exclusively focuses on the question of whether the complex features of organisms are best explained as the result of intelligent or unintelligent causes.

1.2.2 Definition used here for "scientific theory"

Is intelligent design a "scientific theory"? As shown in section 1.1 the word "theory" has multiple meanings. It is my opinion that the relevant dictionary definition for that term in the present context is "the analysis of a set of facts in their relation to one another".¹³ In other words, a "theory" is a proposed explanation for a set of facts. I have argued in the philosophy of science journal *Biology and Philosophy* that a "scientific" theory is a theory which is constructed solely on the foundation of empirical facts about the natural world and logical inferences.¹⁴ Since it is supposed to be based solely on empirical facts and logical inferences, a "scientific" theory should not tailor its claims to agree with authoritative sources, such as the scriptures of any religion or the statements of any religious or governmental leaders, nor should it tailor its claims to disagree with them. Neither should a "scientific" theory deliberately adjust its claims to agree with prevailing expectations among scientists in general of what sorts of phenomena should exist in the universe, nor should it adjust its claims to disagree with them. Rather, a scientific theory should be developed in utter disregard of any factors other than the physical, empirical evidence.

1.2.3 Why ID is a scientific theory

1.2.3.1 The appearance of design in biology

ID is a "theory" because, as discussed above in 1.2.2, it is a proposed explanation for a set of facts. It is a "scientific" theory because, as in 1.2.2, it is based entirely on empirical, observable facts about biology plus logical inferences. The fact that design is indeed based on empirical, observable facts about biology is evident in the writings of some biologists who are not proponents of intelligent design. For example, Francis Crick, the recently deceased Nobel laureate and co-discoverer of the shape of DNA, wrote that, "Biologists must constantly keep in mind that what they see was not designed, but rather evolved".¹⁵ Apparently they must strive so hard to do this because the appearance of design in life is so strong. Brandeis University biologist David DeRosier, a scientist who does research on

the bacterial flagellum, which is a structure that many bacteria use to swim through liquid, remarked in the science journal *Cell* that "More so than other motors, the flagellum resembles a machine designed by a human."¹⁶ (A copy of a drawing of the bacterial flagellum which appears in the university textbook *Biochemistry* by Voet and Voet is included as Exhibit 2.) In 1998 a special edition of *Cell* was devoted to the topic of "Macromolecular Machines" — that is, structures found in the cell which are literally machines made out of molecules. Articles in the journal had titles such as: "The Cell as a Collection of Protein Machines"; "Polymerases and the Replisome: Machines within Machines"; and "Mechanical Devices of the Spliceosome: Motors, Clocks, Springs, and Things". Commentary on the page containing the Table of Contents effused:

Like the machines invented by humans to deal efficiently with the macroscopic world, protein assemblies contain highly coordinated moving parts. Reviewed in this issue of *Cell* are the protein machines that control replication, transcription, splicing ... —the machines that underlie the workings of all living things.¹⁷

In other words the cell — the foundation of life — contains systems that function like sophisticated, designed machinery. A copy of the cover of the issue of *Cell*, as well as a copy of its table of contents, is included as Exhibit 3.

1.2.3.1.1 Richard Dawkins on the appearance of design in biology

That biology exudes the appearance of design is insisted upon by one of the foremost proponents of Darwin's theory, Oxford University biologist Richard Dawkins. On the first page of his book *The Blind Watchmaker* Dawkins bluntly observes, "Biology is the study of complicated things that give the appearance of having been designed for a purpose."¹⁸ As a Darwinist, Dawkins thinks that in reality natural selection accounts for the appearance of design. Nonetheless, he states strongly that the appearance of design in life is overpowering:

Natural selection is the blind watchmaker, blind because it does not see ahead, does not plan consequences, has no purpose in view. Yet the living results of natural selection overwhelmingly impress us with the appearance of design as if by a master watchmaker, impress us with the illusion of design and planning.¹⁹

Dawkins writes that design can easily be recognized from the physical attributes of a system:

We may say that a living body or organ is well designed if it has attributes that an intelligent and knowledgeable engineer might have built into it in order to achieve some sensible purpose, such as flying, swimming, seeing ...²⁰

Dawkins further points out that a system does not have to be perfect to have the marks of design:

It is not necessary to suppose that the design of a body or organ is the best that an engineer could conceive of. ... But any engineer can recognize an object that has been designed, even poorly designed, for a purpose, and he can usually work out what that purpose is just by looking at the structure of the object.²¹

1.2.3.1.2 The lack of rigorous, detailed Darwinian explanations for the appearance of design in biology

Proponents of Darwin's theory such as Richard Dawkins are convinced that natural selection can account for the strong appearance of design in biology. However, like proponents of complexity theory, proponents of intelligent design theory are skeptical of the Darwinian claim, and deny that random mutation and natural selection have been shown to account for some complex aspects of life.

Some scientists who are not proponents of intelligent design freely admit that Darwinian theory has so far been unable to give rigorous, detailed explanations for the complex biochemical machinery discovered in the cell by modern science. For example, in *The Way of the Cell*, published by Oxford University Press in 2001, while considering the claims of intelligent design proponents Colorado State University emeritus microbiologist Franklin M. Harold wrote that:

[W]e must concede that there are presently no detailed Darwinian accounts of the evolution of any biochemical system, only a variety of wishful speculations.²²

When reviewing my book, *Darwin's Black Box: The Biochemical Challenge to Evolution*, which argued that Darwinian explanations have not yet been given for complex biochemical systems, for the science journal *Nature*, University of Chicago evolutionary biologist Jerry Coyne wrote:

There is no doubt that the pathways described by Behe are dauntingly complex, and their evolution will be hard to unravel.... We may forever be unable to envisage the first proto-pathways.²³

The point is that some scientists who are not at all sympathetic to ID nonetheless admit that Darwinian theory has not given detailed, testable explanations for the Darwinian evolution by random mutation and natural selection of complex biochemical systems in the cell. *Thus the path is open to alternative explanations.*

1.2.3.2 Intelligent design reasoning

Intelligent design proponents start from **the same** observable facts as do other scientists such as Richard Dawkins, and notice **the same** strong resemblance of some biological systems, such as the molecular machinery of the cell, to systems we know to be designed. ID advocates also notice that other theories, such as complexity theory or Darwinian natural selection, have not yet given satisfactory accounts, as many scientists freely admit. Thus, ID proponents see a situation where science has discovered that life contains many systems that strongly appear to have been designed and for which no non-design explanation is in hand. ID then advances the plain, straightforward proposal that perhaps the complex structures and molecular machinery of the cell appear designed because they actually were designed by an intelligent agent. I summarized the intelligent design argument in a recent New York Times op-ed, which is included as Exhibit 4.

Although saying that parts of life were actually designed strikes many scientists and other people as unexpected and unsettling, the logic of the design argument is a simple inductive argument (inductive arguments are common and important in science²⁴): Whenever we see functional systems of a certain degree and type of complexity in our everyday world, we have always found them to be designed. Now we have discovered such complex systems in the cell. Since we currently have no other explanation for the origin of such systems, we are justified in extending the induction to the cell, and concluding that there may have been real design involved in its construction.

1.2.3.2.1 An analogy between intelligent design theory and the theory of the Big Bang

The logic of the argument for intelligent design in biology is in some ways similar to that used when the Big Bang theory was first proposed in the earlier 20th century. In the 19th and early 20th century many physicists thought that the universe was eternal and unchanging. Then it was unexpectedly observed that the light from many galaxies was shifted in wavelength toward the red end of the spectrum. This meant that the galaxies were rapidly moving away from the earth and away from each other. Because this is the pattern observed after an explosion in our common experience, by using inductive reasoning the data could be interpreted to be pointing to the aftermath of a huge explosion of the universe itself. This further suggested that the universe was not eternal and unchanging, but may have had a beginning.²⁵

The Big Bang theory struck some scientists as having religious overtones — perhaps the Big Bang was initiated from outside of nature, perhaps it was even a supernatural creation event — and because of this some scientists disliked the theory.²⁶ But the Big Bang theory was not justified by any religious text or dogma. Rather, it was justified by the strong pattern of an explosion suggested by the data. I have written in the philosophy of science journal *Biology and Philosophy* that I think intelligent design theory is similar to the Big Bang theory in the following respect.²⁷ Some people may worry that the theory has religious overtones, but science should ignore any extra-scientific overtones and focus exclusively on the data. Like the Big Bang, intelligent design is justified by the pattern of the physical data.

1.2.3.3 Scientific theories, intelligent design, and falsifiability

Some philosophers of science have argued that one mark of a scientific theory is that it is falsifiable.²⁸ On the other hand, other philosophers of science strongly disagree that falsifiability is a necessary mark of a scientific theory, or that other simple criteria reliably demarcate science from non-science.²⁹ Some scientists have claimed that a theory of intelligent design is unfalsifiable and therefore is not scientific.³⁰ On the other hand, other scientists have actually advanced scientific claims intended to falsify ID, showing that they think ID is indeed falsifiable.³¹ (I have rebutted their claims that ID had been shown to be wrong, arguing instead that the science behind their claims was either mistaken or not pertinent.)³² I have argued in an article in the philosophy of science journal *Biology and Philosophy* that intelligent design theory is falsifiable.³³ The point is that the necessity for

a “scientific” theory to be falsifiable is disputed, but that, in any event, ID is indeed falsifiable.

2 Intelligent Design is not “Creationism”

2.1 Definition of “creationism”

Is ID “creationism”? To answer that question we must first decide what “creationism” is. Some people use the word “creationism” very broadly to indicate any belief that a supernatural being has affected nature in any way. For example, in 1987 John Maddox, then the editor of the prominent science journal *Nature*, wrote an editorial in *Nature* entitled “Down with the Big Bang” that argued that the Big Bang theory was “philosophically unacceptable”, partly because it gave succor to “creationists”:

Creationists and those of similar persuasions seeking support for their opinions have ample justification in the doctrine of the Big Bang. That, they might say, is when (and how) the Universe was created.³⁴

Nonetheless, the common usage of the word “creationism” indicates “the literal belief in the account of creation given in the Book of Genesis”.³⁵ Thus in popular usage a “creationist” is a person who thinks the world is relatively young, on the order of ten thousand years, and that the major categories of organisms were created ex nihilo by a supernatural being, God.

2.2 ID requires none of the presumptions of creationism

Intelligent design theory is not creationism because intelligent design theory does not require belief in any tenet of creationism. As discussed in section 1.2.1, intelligent design theory focuses exclusively on the question of whether biological systems, such as the molecular machinery found in cells, exhibit features consistent with actual intelligent design. As interesting as they may be, the topics of when such designing occurred, who did the designing, why it was done, how it was done, and so forth, are further, additional questions — beyond the basic question of whether there is design present — for which the scientific evidence is yet insufficient to draw a firm conclusion.

Interestingly, a “creationist” does not at all have to think that biology shows physical, empirical signs of design. A “creationist” can simply believe in creation based on faith in a religious text, private religious experience, or some other source, without consideration of nature at all. Although he was not a “creationist” in our modern sense of the term, the 19th century Englishman Cardinal John Henry Newman exemplified that attitude. In his *Letters and Diaries* he wrote, “I believe in design because I believe in God, not in a God because I see design.”³⁶ In other words, strong religious faith does not require that biology show any physical evidence of design of the kind of which the Darwinian evolutionary biologist Richard Dawkins writes (see section 1.2.3.1.1), or that Brandeis University biologist David DeRosier sees in the bacterial flagellum (sections 1.2.3.1).

One can be a "creationist" in the popular sense of that word and think biology does show signs of design, but one certainly need not be. For example, as I discussed in my book *Darwin's Black Box*³⁷ and in an article in the philosophy of science journal *Biology and Philosophy*,³⁸ one is free to suppose, based on nonscientific reasons, that the designer was a natural being, such as a time traveler or space alien. (Francis Crick, the Nobel laureate, once proposed in an article entitled "Directed Panspermia" in the science journal *Icarus* that the origin of life on earth may have been the result of the deliberate seeding of life here by spores sent by intelligent space aliens.³⁹ A copy of Crick's article is included as Exhibit 5.) Indeed, there is at least one group (the "Raelians") who profess to believe that humans were designed by space aliens.⁴⁰

One can also hold that the designer is some other, yet unexplained, natural entity. If one decides, on the basis of nonscientific reasons, that the designer is a supernatural being, then one can hold that the designer is a subordinate supernatural being such as the "demiurge" of Plato.⁴¹ If one supposes that the designer is a supreme supernatural being, God, then it may be the God of any religion, such as that of Christianity, Islam, Hinduism, Native American religions, or others. Or one can simply keep an open mind, and think that the question of the identity of the designer has yet to be resolved with any firmness.

One can also think, unlike a "creationist", that a designer set up the universe to unfold in a planned way over immense times, to give rise to the complex structures science has discovered in life, without any discernible exception to natural laws. I discussed this view in a letter to the editor published in the July 2001 edition of the NCSE Reports. The newsletter is published by the National Center for Science Education, which vigorously promotes the teaching of Darwinian evolution in schools. The letter is reproduced below:

In their article "Of Mousetraps and Men: Behe on Biochemistry" (Reports of the NCSE 20, 25-30, 2000), which has just come to my attention, Shanks and Joplin appear to mistakenly attribute to me the contention that irreducibly complex biochemical systems must have been created ex nihilo. I have never claimed that. I have no reason to think that a designer could not have used suitably modified pre-existent material. My argument in *Darwin's Black Box* is directed merely toward the conclusion of design. How the design was effected is a separate and much more difficult question to address. Although creation ex nihilo is a formal possibility, design might have been produced by some other means which involved no discontinuities in natural law, even if the designer is a supernatural being. One possibility is directed mutations. As noted by Brown University biologist Kenneth Miller in *Finding Darwin's God*, "The indeterminate nature of quantum events would allow a clever and subtle God to influence events in ways that are profound, but scientifically undetectable to us. Those events could include the appearance of mutations...." I have no reason to object to that as a route to irreducibly complex systems. I would just note further that such a process amounts to intelligent design, and that while we may be unable to discern the means by which the design is effected, the resultant design itself may be detected in the structure of the irreducibly complex system.

The core claim of intelligent design theory is quite limited. It says nothing directly about how biological design was produced, who the designer was, common descent, or other such questions. Those can be argued separately. It says only that design can be empirically detected in observable features of physical systems. As an important corollary, it also predicts that mindless processes—such as natural selection or the self-organization scenarios favored by Shanks and Joplin—will not be demonstrated to be able to produce irreducible systems of the complexity found in cells.⁴²

None of the possibilities discussed above requires that the picture of the universe developed by modern science be repudiated. The only assertion that intelligent design theory itself properly makes is that some aspects of biology are indeed the product of intelligent design. As discussed earlier in section 1.2.3, this assertion is actually quite consistent with the evidence of biology, although at odds with the claims of Darwinism. The point is that intelligent design theory does not require a person to adhere to any tenet usually associated with the word "creationism". A "creationist" does not have to believe in physically-discernible intelligent design, and an ID proponent does not have to believe in "creationism".

- 3 What are the gaps and problems with the Darwinian theory of evolution?
- 3.1 The problem of the origin of new, complex biological features

It is my scientific opinion that the primary problem with Darwin's theory of evolution is the lack of detailed, testable, rigorous explanations for the origin of new, complex, biological features, as explained above in section 1.2.3.1.2. This problem was recognized in the 19th century, shortly after Darwin published *The Origin of Species*, by biologists such as St. George Mivart ("What is to be brought forward [against Darwin's theory] may be summed up as follows: That "Natural Selection" is incompetent to account for the incipient stages of useful structures..."⁴³, and continues to be a problem today. Although vague stories and speculations are sometimes offered, rarely are such stories testable in a way that could falsify the claim that the complex feature was produced in a Darwinian fashion. For example, as stated above in section 1.2.3.1.2, in the case of the molecular machinery found in cells Franklin M. Harold wrote that: "[W]e must concede that there are presently no detailed Darwinian accounts of the evolution of any biochemical system, only a variety of wishful speculations." And Jerry Coyne wrote "There is no doubt that the pathways described by Behe are dauntingly complex, and their evolution will be hard to unravel.... We may forever be unable to envisage the first proto-pathways." *It is extremely difficult or impossible to test — or even meaningfully critique — "wishful speculations" or unenvisaged proto-pathways.*

It should be strongly emphasized that under this broad category of difficulties lies much of the structure and development of life, including: the existence of the genetic code; transcription of DNA; translation of mRNA; the structure and function of the ribosome; the structure of the cytoskeleton; nucleosome structure; the development of new protein-protein interactions; the existence of the proteasome; the existence of the endoplasmic reticulum; the existence of motility organelles such as the bacterial flagellum and the eukaryotic cilium; the development of the pathways for the construction of the cilium and flagellum; the existence of the defensive apparatus such as the immune system and blood clotting system; and much else. The existence of such unresolved difficulties for Darwinian theory at the molecular level of life makes it reasonable to wonder if a Darwinian framework is the right way to approach such questions. It also makes it reasonable to wonder if Darwinian processes explain major new features of life at higher levels, such as the level of organs and organisms.

3.2 The problem of falsification

There are other major difficulties and problems for Darwin's theory as well. One is the great difficulty in falsifying it. That is, in finding a fact of nature that would be taken by Darwinists as evidence against their theory. For example, for many years in biology textbooks students were shown drawings of vertebrate embryos that looked remarkably similar. The embryos were drawn by the 19th century embryologist Ernst Haeckel, an admirer of Darwin. The striking similarity was thought to strongly support Darwin's theory, that the different classes of vertebrates descended by natural selection from a common ancestor. The rationale for thinking so was given in the widely-used, college-level textbook *Molecular Biology of the Cell*, where president of the National Academy of Sciences Bruce Alberts and other co-authors wrote that:

Early developmental stages of animals whose adult forms appear radically different are often surprisingly similar... Such observations are not difficult to understand.... The early cells of an embryo are like cards at the bottom of a house of cards—a great deal depends on them, and even small changes in their properties are likely to result in disaster.⁴⁴

In other words, evolution would be expected to conserve the structure of the early embryos, inherited from a common ancestor. Natural selection would not be expected to change such a "locked-in", fundamental structure.

However, in 1997 an international team led by the British embryologist Michael Richardson showed that Haeckel's drawing were very misleading, and that there were significant differences between the embryos. A story entitled "Haeckel's embryos: fraud rediscovered" in the journal *Science* put it this way:

Not only did Haeckel add or omit features ... but he also fudges the scale to exaggerate similarities among species, even when there were 10-fold differences in size. Haeckel further blurred differences by neglecting to name the species in most cases, as if one representative was accurate for an entire group of animals. In reality ... even closely related embryos such as those of fish vary quite a bit.⁴⁵

Nonetheless, the discovery that the embryos looked very different from what they were pictured in textbooks did not at all cause Bruce Alberts or other scientists to question Darwinian theory. Yet if a theory is equally compatible with one result (nearly identical embryos) and its opposite (variable embryos) than how can it be rigorously tested? If Darwinian theory is compatible with false data, such as the original drawings of Haeckel, then how can we know if the theory is wrong? A story from the *New York Times*, "Biology Text Illustrations More Fiction Than Fact" (which is a sidebar in the longer story "Darwin vs. Design: Evolutionists' New Battle"), concerning the case of Haeckel's embryos is included as Exhibit 6.⁴⁶

3.3 The "crisis" of sex

Another major, longstanding difficulty of Darwinian theory that is little appreciated by the general public is the problem of sexual reproduction. It was recognized as early as the late

19th century that Darwinian theory predicted sexual reproduction should be rare. The reason is that in sexual reproduction a given organism only gets half of its genes reproduced in any particular one of its offspring; its sexual partner contributes the other half. However, if an organism reproduced asexually, then it could contribute all of its genes to each of its offspring. The reason that, contrary to the straightforward expectation of Darwinian theory, sex is common has been debated for over a hundred years. There are so many competing ideas about why sexual reproduction should occur that A. S. Kondrashov, in an article in the *Journal of Heredity* in 1993, found it necessary to try to classify all the hypotheses into groups to keep better track of them!

After more than a century of debate, the major factors of the evolution of reproduction are still obscure. During the past 25 years, hypotheses have become so numerous and diverse that their classification is a necessity. The time is probably ripe for this: no fundamentally new hypothesis has appeared in the last 5 years, and I would be surprised—and delighted—if some important idea remains unpublished.⁴⁷

The debate continues, with various theories offered by various scientists, but with no accepted resolution of the problem. For example in 1998 the journal *Science* devoted a special section of one issue to the evolution of sex, with articles such as “Why Sex? Putting Theory to the Test” and “Why Sex and Recombination?” One introductory article remarked,

Yet how sex began and why it thrived remain a mystery. ... Why did sex overtake asexual reproduction some billion or more years ago, and why does it continue to upstage asexuals? ... Biologists have come up with a profusion of theories since first posing these questions a century ago. ... Sex is a paradox in part because if nature puts a premium on genetic fidelity, asexual reproduction should come out ahead. It transmits, intact, a single parental genome that is by definition successful. Sexual reproduction, on the other hand, involves extensive makeovers of the genome. The production of gametes requires recombination, in which the two copies of each chromosome pair up and exchange DNA. Fertilization, in which genes from different parents fuse, creates yet more genetic combinations. All this shuffling is more likely to break up combinations of good genes than to create them—yet nature keeps reshuffling the deck.⁴⁸

(Notice again that the word “theories” is used above to mean competing, tentative ideas — *not* “well-substantiated explanations”.) In his 1975 book *Sex and Evolution* the prominent evolutionary biologist George C. Williams wrote:

This book is written from a conviction that the prevalence of sexual reproduction in higher plants and animals is inconsistent with current evolutionary theory ... there is a kind of crisis at hand in evolutionary biology ...⁴⁹

While discussing Williams remarks on sex, in 2004 Richard Dawkins wrote:

Maynard Smith and Hamilton said similar things. It is to resolve this crisis that all three Darwinian heroes, along with others of the rising generation, laboured. I shall not attempt an account of their efforts, and certainly I have no rival solution to offer myself.⁵⁰

Yet if Darwinian theory has no good account for sexual reproduction, then the very heart of the theory of evolution — the differential reproduction of organisms — is floating in midair.

A theory of evolution that predicts most species should be asexual is like a theory of gravity

that predicts that most objects will fall up. Either conundrum should make a reasonable person wonder if the proposed theory might be missing some large piece of the puzzle. Furthermore, if Darwinists have tolerated such a large, acknowledged difficulty in the center of their theory for over a hundred years, then one might wonder if they are unreasonably attached to it. Students should be aware of this.

It should be emphasized that the problem with sex is not simply the problem of how the intricate machinery of meiosis, recombination, and other sexual processes could develop in the gradual, undirected manner that Darwinian theory envisions. The theory encounters that difficulty in the explanation of *all* complex biological systems. Rather, the difficulty in explaining sex is the question of why, on Darwinian principles, it should exist at all, even if there were a gradual way to develop it. On straightforward Darwinian principles, sex appears detrimental to the interests of the organism.

4 The origin of life

A major problem for Darwin's theory is the unsolved mystery of the origin of life. Darwin's theory doesn't itself deal with the origin of life; rather, it presupposes that life was present on earth in a form that would be able to undergo evolution by random mutation and natural selection. Even in principle, Darwin's theory cannot account for the origin of life, because the theory concerns the reproduction of already-living organisms. Thus before the beginning of life the earth was missing a prerequisite ingredient for Darwinian evolution to occur.

The problem that the origin of life poses for Darwin's theory is the following. If the beginning of life required something extra, something in addition to the unintelligent operation of natural processes that Darwin's theory invokes, then it would be fair for a curious inquirer to wonder if those other processes ended with the beginning of life, or if they continued to operate throughout the history of life. The acknowledgment of difficulties with the origin of life would likely make it more urgent that Darwinists actually demonstrate that random mutation and natural selection can do what they claim, rather than relying on the presumption that they can.

The importance of the origin of life to Darwin's theory is seen in the fact that high school biology textbooks include a section dealing with the topic. This often leads into discussion of the first cells and then into Darwinian evolution, so that it can appear to the student to be a seamless process. Sometimes a text gives students little warning (or the warning is not emphasized so that students easily overlook it) that the origin of life is an unsolved problem that has remained a mystery despite fifty years of active scientific investigation.

It is easy to find comments by knowledgeable scientists that attest to the lack of progress in the field of origin of life studies. For example, in a recent interview with the PBS science program Nova, the distinguished paleontologist Andrew Knoll, who is the Fisher Professor of Natural History at Harvard University and a leading expert on early life on earth, remarked: "The short answer is we don't really know how life originated on this planet." In response to the interviewer's question, "Will we ever solve the problem [of the origin of

life]?", Knoll responded, "I imagine my grandchildren will still be sitting around saying that it's a great mystery..."⁵¹

The widely-used, university-level textbook "Biochemistry" by Voet and Voet introduces a section on the origin of life with the following remarks:

In the remainder of this section, we describe the most widely favored scenario for the origin of life. *Keep in mind, however, that there are valid scientific objections to this scenario as well as to the several others that have been seriously entertained, so that we are far from certain as to how life arose.*⁵² [italics in the original]

In other words, like with the problem of sex, there is a profusion of theories, none of which is satisfactory.

In its booklet *Science and Creationism* the National Academy of Sciences called the problem of the origin of life "seemingly intractable." Nonetheless, the National Academy writes:

For those who are studying the origin of life, the question is no longer whether life could have originated by chemical processes involving nonbiological components. The question instead has become which of many pathways might have been followed to produce the first cells.⁵³

This statement subtly shifts the spotlight away from the actual scientific *problem* of the origin of life and onto the subjective *attitudes* of workers in the field. In effect it encourages teachers (to whom the booklet is addressed) to inculcate in their students the presumption that the problem of the origin of life must be addressed in the framework of unintelligent "chemical processes involving nonbiological components". This despite the fact that such a framework has been unsuccessful over the course of half of a century: Students are not encouraged to think, or given any reason to think, that such a framework might possibly be wrong. Students are encouraged to follow in the footsteps of the failures of the past fifty years.

One can also discern in another, quite remarkable passage in *Science and Creationism* the desire to inculcate into students the presumption that "chemical processes involving nonbiological components" simply must be responsible for the origin of life. There the National Academy of Sciences speaks glowingly of a particular *theological* stance, called "theistic evolution", as if the Academy — an organization chartered by the federal government — were expert on religious matters.

Many religious persons, including many scientists, hold that God created the universe and the various processes driving physical and biological evolution and that these processes then resulted in the creation of galaxies, our solar system, and life on Earth. This belief, which sometimes is termed "theistic evolution," is not in disagreement with scientific explanations of evolution. Indeed, it reflects the remarkable and inspiring character of the physical universe revealed by cosmology, paleontology, molecular biology, and many other scientific disciplines.⁵⁴

A teacher reading that section could easily pick up the Academy's apparent attitude toward religion: theistic evolution, where laws operate continuously — good; religious ideas

requiring interruption of natural laws — bad. A teacher influenced by the Academy's booklet might possibly attempt to influence the religious beliefs of students in the same way.

5 The scientific controversy over intelligent design

My book, *Darwin's Black Box: The Biochemical Challenge to Evolution*, presented the argument that Darwinian processes are unlikely explanations for the biochemical complexity that modern science has found in the cell. Instead, the book argued, a more likely explanation is deliberate intelligent design. Since shortly after the book was published in 1996 scientists who support Darwin's theory of evolution by random mutation and natural selection have offered arguments to try to refute the contention of intelligent design. In turn I have offered counterarguments to show why the Darwinian arguments fail. I think it is safe to say that so far neither side has been persuaded by the other's arguments. Below I will list some of the articles that have been published on both sides.

1) In a symposium published by *Boston Review* in its Feb/March 1997 issue, a dozen academics traded essays arguing the relative merits of intelligent design, Darwinism, and other ideas for explaining the development of life. The essays are available on line.⁵⁵ Contributing authors include:⁵⁶

Michael Behe, professor of biological sciences, Lehigh University
Phillip E. Johnson, professor of law, University of California, Berkeley,
David Berlinski, a writer and mathematician,
Jerry A. Coyne, professor of evolutionary biology, University of Chicago
Russell F. Doolittle, professor of biochemistry, University of California, San Diego
Douglas J. Futuyma, professor of evolutionary biology, State University of New York, Stony Brook
Robert DiSilvestro, professor of nutritional biochemistry, Ohio State University
Michael Ruse, professor of philosophy, University of Guelph
James A. Shapiro, professor of biochemistry, University of Chicago
Daniel Dennett, professor of philosophy, Tufts University
H. Allen Orr, professor of evolutionary biology, University of Rochester

2) In 1999 Kenneth Miller, a professor of biology at Brown University, published *Finding Darwin's God*⁶⁷ (HarperCollins). In the book he defended Darwinian evolution. One of the chapters of the book, Chapter 5 "God the Mechanic", criticizes my argument in *Darwin's Black Box* for intelligent design, and offers scientific arguments against it.

3) In 2001 Robert T. Pennock, professor of philosophy at Michigan State University, edited a book entitled *Intelligent Design Creationism and Its Critics*⁵⁸, which was published by MIT Press. The book collected dozens of essays. Each essay by a proponent of intelligent design was subjected to several critical essays by opponents. Proponents usually were not given space to respond to criticisms. Several of the essays concerned the scientific claims of intelligent design.

4) In 1999 Shanks and Joplin published a review of *Darwin's Black Box* in the journal *Philosophy of Science*⁵⁹. They argued that the idea of irreducible complexity (which I discussed in the book) was incorrect, and that complex biochemical systems could develop through a means they called "redundant complexity."

5) In 2000 I replied to Shanks and Joplin's criticisms in an article also published in *Philosophy of Science*⁶⁰. I argued that their criticisms of irreducible complexity were themselves flawed. A copy of the article is included as Exhibit 7.

6) In 2001 I published an article entitled "Reply to my critics: A response to reviews of *Darwin's Black Box: the biochemical challenge to evolution*" in the journal *Biology and Philosophy*⁶¹. The article responds to many of the criticisms in books and articles listed above, including those of scientists Kenneth Miller, Russell Doolittle, H. Allen Orr, Jerry Coyne. A copy of the article is included as Exhibit 8.

7) In 2000 Thornhill and Ussery published an article in the *Journal of Theoretical Biology* arguing against the concept of irreducible complexity.⁶²

8) In 2000 a conference organized by William Dembski was held at Baylor University. It was entitled "the Nature of Nature", and brought together intelligent design proponents and opponents, including many scientists, mathematicians, and philosophers, as well as several Nobel laureates and members of the National Academy of Sciences.⁶³

9) In 2003 Lenski et al published an article in the journal *Nature* entitled "The evolutionary origin of complex features".⁶⁴ The article concerned the ability of a computer program to develop the ability to perform new functions. It was intended to be a model for how biological features might develop in organisms and possibly get around the difficulty of irreducible complexity.

10) In 2004 Young and Edis edited a volume entitled *Why Intelligent Design Fails: A Scientific Critique of the New Creationism*⁶⁵ (Rutgers University Press) which, as its title suggests, offered scientific arguments against intelligent design.

11) In 2004 Dembski and Ruse edited *Debating Design: From Darwin to DNA*⁶⁶ (Cambridge University Press), which included contributions from proponents and opponents of intelligent design, as well as contributions from complexity theorists, who disagree with some of the claims of both intelligent design and Darwinian theory, as well as theistic evolutionists. A copy of my chapter in the volume, which responds to criticisms of irreducible complexity and intelligent design, is included as Exhibit 9.

12) In 2004 Behe and Snoke published an article in the journal *Protein Science* entitled "Simulating evolution by gene duplication of protein features that require multiple amino acid residues"⁶⁷. The article attempts to show the difficulty of evolving a new protein feature by random mutation and natural selection when multiple changes are needed for a new function. A copy of the article is included as Exhibit 10.

One point of this compilation is to show that some Darwinian scientists have responded to

intelligent design with scientific arguments that attempt to falsify it — to show ID to be incorrect. Although I think their scientific arguments are incorrect, the fact that scientists offer such arguments demonstrates that intelligent design is amenable to scientific investigation and criticism. It is therefore a scientific claim.

6 The utility of design as a scientific theory

6.1 A scientific theory does not need to be utilitarian

A scientific theory does not have to have an immediately-obvious utilitarian application to be correct. One of the purposes of science is simply to describe nature accurately. If a theory does that, or at least is better than competing theories at describing nature, then it is fulfilling an important purpose of a scientific theory. In the view of proponents of intelligent design theory, ID more accurately describes what we observe in nature than do competing theories. As explained earlier, some scientists admit that Darwinian theory does not have detailed, rigorous explanations for some of the complex systems that have been discovered in the cell. And some scientists such as Richard Dawkins readily admit that aspects of biology strongly appear to have been designed. Thus it is reasonable to conclude, as ID proponents do, that intelligent design is a more accurate description of aspects of nature than other theories.

6.2 Where is the border between design and unintelligent natural processes?

One use of a theory of intelligent design might be to prod scientists to look for limits to the efficacy of the Darwinian processes of random mutation and natural selection, which might lead to describing nature more accurately. If one has reason to believe, as proponents of ID do, that not all of biology can be explained by natural selection, then one can begin to look for the borders of Darwinian processes. A question such as, what are the limits of Darwinian processes in explaining life on earth?, does not easily occur to a Darwinist, who takes it as an assumption that Darwinian processes explain most complex biological systems. A small step toward addressing such questions was recently taken by myself and David Snoke, a professor of physics at the University of Pittsburgh. We recently published an article in the journal *Protein Science* entitled "Simulating evolution by gene duplication of protein features that require multiple amino acid residues". The article attempts to show the difficulty of evolving a new protein feature by random mutation and natural selection when multiple changes are needed for a new function. A copy of the article is included as Exhibit 10.

6.3 Health implications for a limit to Darwinian evolution

Although a scientific theory does not have to have practical implications in order to be correct, a theory of intelligent design nonetheless might be important in understanding such things as the limits of the development of antibiotic resistance, which of course could have great importance for public health. Here is why. It is well known that bacteria and other microorganisms can develop resistance to some antibiotic drugs, and that this is a

formidable public health threat. It is less well known that some bacteria have been unable to develop resistance to some drugs. The reason is that some antibiotic resistance genes do not have the "evolutionary potential" to develop resistance. This is exemplified in some recent articles from the laboratory of Professor Barry G. Hall at the University of Rochester. Although he is not an advocate of intelligent design, Professor Hall nonetheless does not automatically assume that Darwinian processes can do everything. For example, he writes in a paper in the journal *Antimicrobial Agents and Chemotherapy*: "Instead of assuming that metallo- β -lactamases will evolve rapidly, it would be highly desirable to accurately predict their evolution in response to carbapenem selection." Using a method he developed, he predicts that bacteria will be unable to develop resistance to an antibiotic called imipenem. He writes in the abstract of his article: "The results predict, with >99.9% confidence, that even under intense selection the IMP-1 β -lactamase will not evolve to confer increased resistance to imipenem." A copy of Hall's article is included as Exhibit 11.

If intelligent design theory is correct, and there are limits to what unaided nature can do, then if we understand in more detail what those limits are, we may be able to design more effective antibiotics, ones to which bacteria will be unable to develop resistance.

I should emphasize that this is just one possible application of intelligent design theory, which may or may not be easily successful. The overarching point, however, is that approaching the study of biology from an intelligent design perspective may afford insights that do not come easily to workers who have a Darwinian perspective.

7 The age-appropriateness of discussing difficulties with Darwin's theory in 9th grade

It is my opinion that discussing difficulties with Darwin's theory is quite appropriate for students in 9th grade, or in whichever grade a high school biology course is given. The reason is that the problems with Darwin's theory are no more difficult to understand than the advantages of Darwin's theory. Indeed, the difficulties are often just the reverse of the advantages. Even molecular difficulties with the theory are appropriate for high school students. In many high school biology texts, students are taught of the underlying chemical, biochemical, genetic, and cellular bases of life. If the students can understand such topics, then they can understand difficulties that arise for Darwinian theory at this level. My opinions on this topic are summarized in a *New York Times* op-ed piece "Teach Evolution—And Ask Hard Questions", which is included as Exhibit 12.

Signed: Michael J. Behe Date: 3/24/65

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