Gauging Intelligent Design's Success

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ABSTRACT: Proponents of intelligent design have been remarkably successful, at least in the United States, in creating a cultural movement. They have also been remarkably successful at exasperating a scientific and intellectual world that dismisses intelligent design as the latest incarnation of creationism—more sophisticated than previous incarnations to be sure, but with many of the old faults. In this paper I want to focus on intelligent design's merits as an intellectual project. I will show that the questions it raises are legitimate and cannot be dismissed on a priori grounds. Having demonstrated that intelligent design constitutes a valid intellectual project, I want next to review intelligent design's progress to date. Finally, I will indicate certain milestones that intelligent design needs to achieve before it can expect broad recognition from the scientific community that it is making a fruitful contribution to our understanding of the natural world.

1. A Method for Detecting Design

Intelligent design is the science that studies signs of intelligence. Because a sign is not the thing signified, intelligent design does not speculate about the intentions of a designer. Intelligent design's focus is not on a designer's intentions (the thing signified) but the designed objects attributable to a designer's intentions (the sign). What a designer intends is an interesting question, and one may be able to infer something about a designer's intentions from the designed objects that a designer produces. But the intentions of a designer and even the nature of a designer (whether, for instance, the designer is a conscious personal agent or an impersonal telic process) lie outside the scope of intelligent design. As a scientific research program, intelligent design investigates the effects of intelligence and not intelligence as such.

What makes intelligent design controversial is that it purports to find signs of intelligence in biological systems. According to Francisco Ayala (1994, 4), Darwin's greatest achievement was to show how the organized complexity of organisms could be attained without a designing intelligence. Intelligent design therefore directly challenges Darwinism and other naturalistic approaches to the origin and evolution of life. Design has had a turbulent intellectual history. The main difficulty with it in the last 200 years has been discovering a conceptually powerful formulation of it that will fruitfully advance science. What has kept design outside the scientific mainstream since the rise of Darwinism is that it lacked precise methods for distinguishing intelligently caused objects from unintelligently caused ones.

For design to be a fruitful scientific concept, scientists have to be sure they can reliably determine whether something is designed. For instance, Johannes Kepler thought the craters on the moon were intelligently designed by moon dwellers. We now know that the craters were formed by blind material processes (like meteor impacts). It's this fear of falsely attributing something to design only to have it overturned later that has prevented design from entering the natural sciences proper. But proponents of intelligent design argue that they now have formulated precise methods for discriminating designed from undesigned objects. These methods, they contend, enable them to avoid Kepler's mistake and reliably locate design in biological systems.

As a theory of biological origins and development, intelligent design's central claim is that only intelligent causes adequately explain certain complex, information-rich structures of biology and that these causes are empirically detectable. To say intelligent causes are empirically detectable is to say there exist well-defined methods that, based on observable features of the world, can reliably distinguish intelligent causes from undirected natural causes. Many special sciences have already developed such methods for drawing this distinction—notably forensic science, cryptography, archeology, and the search for extraterrestrial intelligence (or SETI). Essential to all these methods is the ability to eliminate chance and necessity.

Astronomer Carl Sagan wrote a novel about SETI called *Contact*, which was later made into a Jodie Foster movie. The plot and the extraterrestrials, of course, were fictional, but Sagan based the SETI astronomers' methods of design detection squarely on scientific practice. In other words, real-life SETI researchers have never detected designed signals from distant space, but if they encountered such a signal, as the film's astronomer's did, they too would infer design. Why did the radio astronomers in *Contact* draw such a design inference from the beeps and pauses they monitored from space? SETI researchers run signals collected from distant space through computers programmed to recognize preset patterns. Signals that do not match any of the patterns pass through a design-detecting sieve and are classified as random.

After years of receiving apparently meaningless "random" signals, the *Contact* researchers discovered a pattern of beats and pauses that corresponded to the sequence of all the prime numbers between 2 and 101. (Prime numbers are divisible only by themselves and by one.) That seized their attention, and they immediately detected the activity of a designing intelligence. When a sequence begins with two beats, then a pause, three beats, then a pause ... and continues through each prime number all the way to 101 beats, researchers must infer the presence of an extraterrestrial intelligence.

Here's why. Nothing in the laws of physics requires radio signals to take one form or another, so the prime sequence is *contingent* rather than necessary. Also, the prime sequence is a long sequence and therefore *complex*. Note that if the sequence lacked complexity, it could easily have happened by chance. Finally, it was not just complex but also exhibited an independently given pattern or *specification* (it was not just any old sequence of numbers but a mathematically significant one—the prime numbers).

Intelligence leaves behind a characteristic trademark or signature—what I call *specified complexity*. An event exhibits specified complexity if it is contingent and therefore not necessary; if it is complex and therefore not readily repeatable by chance; and if it is specified in the sense of exhibiting an independently given pattern. Note that a merely improbable event is not sufficient to eliminate chance—flip a coin long enough and you'll witness a highly complex or improbable event. Even so, you'll have no reason not to attribute it to chance.

The important thing about specifications is that they be objectively given and not just imposed on events after the fact. For instance, if an archer fires arrows into a wall, and then we paint bull's-eyes around the arrows, we impose a pattern after the fact. On the other hand, if the targets are set up in advance ("specified"), and then the archer hits them accurately, we know it was by design. Arguably, my most important research contribution has been to lay out the logical and statistical underpinnings for specifications.

In determining whether biological organisms exhibit specified complexity, proponents of intelligent design focus on identifiable systems—such as individual enzymes, metabolic pathways, molecular machines, and the like. These systems are specified in virtue of their independent functional requirements and they exhibit a high degree of complexity. Of course, once an essential part of an organism exhibits specified complexity, then any design attributable to that part carries over to the organism as a whole. One need not demonstrate that every aspect of the organism was designed; in fact, some aspects will be the result of purely natural causes.

The combination of complexity and specification convincingly pointed the radio astronomers in the movie *Contact* to an extraterrestrial intelligence. Specified complexity is the characteristic trademark or signature of intelligence. It is a reliable empirical marker of intelligence in the same way that fingerprints are a reliable empirical marker of a human being's presence. Proponents of intelligent design argue that undirected natural causes cannot generate specified complexity. (My book *No Free Lunch* was devoted entirely to making that case.)

To say that undirected natural causes cannot generate specified complexity is not to say that naturally occurring systems cannot exhibit specified complexity or that natural processes cannot serve as a conduit for specified complexity. Naturally occurring systems can exhibit specified complexity, and nature operating without intelligent direction can take preexisting specified complexity and shuffle it around. But that is not the point. The point is whether nature (conceived as a closed system of blind, unbroken natural causes) can *generate* specified complexity in the sense of originating it when previously there was none.

Take, for instance, a Dürer woodcut. It arose by mechanically impressing an inked woodblock on paper. The Dürer woodcut exhibits specified complexity. But the mechanical application of ink to paper via a woodblock does not account for the woodcut's specified complexity. The specified complexity in the woodcut must be referred back to the specified complexity in the woodblock, which in turn must be referred back to the designing activity of Albrecht Dürer himself (in this case deliberately chiseling the woodblock). Specified complexity's causal chains end not with blind nature but with a designing intelligence.

To sum up, specified complexity is the basis for design inferences across numerous special sciences, including archaeology, cryptography, forensics, and the search for extraterrestrial intelligence (SETI). I detail this in my book *The Design Inference*, a peer-reviewed statistical monograph that appeared with Cambridge University Press in 1998. The actual term specified complexity is not original with me. It first occurs in the origin-of-life literature, where Leslie Orgel (1973, 189) used it to describe what he regards as the essence of life. That was thirty years ago. More recently, in 1999, surveying the state of origin-of-life research, Paul Davies (1999, 112) remarked: "Living organisms are mysterious not for their complexity *per se*, but for their tightly specified complexity." Orgel and Davies used specified complexity loosely. In my own research I've formalized it as a statistical criterion for identifying the effects of intelligence. For identifying the effects of animal, human, and extraterrestrial intelligence the criterion works just fine. Yet when anyone attempts to apply the criterion to the origin of biological systems, controversy erupts. Why is that?

2. Detecting Design in Biology

It is because evolutionary biology teaches that all biological complexity is the result of material mechanisms. These include principally the Darwinian mechanism of natural selection and random variation but also include other mechanisms (symbiogenesis, gene transfer, genetic drift, the action of regulatory genes in development, self-organizational processes, etc.). These mechanisms are just that: mindless material mechanisms that do what they do irrespective of intelligence. To be sure, mechanisms can be programmed by an intelligence. But any such intelligent programming of evolutionary mechanisms is not properly part of evolutionary biology.

Intelligent design, by contrast, teaches that biological complexity is not exclusively the result of material mechanisms but also requires intelligence, where the intelligence in question is not reducible to such mechanisms. The point at issue, therefore, is not the evolutionary relatedness of all organisms, or what is called common descent. Indeed, intelligent design is perfectly compatible with common descent. Rather, the point at issue is how biological complexity emerged and whether intelligence played an indispensable (which is not to say exclusive) role in its emergence.

Suppose, therefore, for the sake of argument that intelligence—one irreducible to material mechanisms—actually did play a decisive role in the emergence of life's complexity and diversity. How could we know it? Certainly specified complexity will be required. Indeed, if specified complexity is absent or in doubt, then the burden of evidence is on those who want to deny that material mechanisms can explain the biological systems under investigation. Conversely, to the degree that specified is confirmed, the burden of evidence shifts to those who want to maintain that material mechanisms provide an adequate explanation.

In the face of this seemingly reasonable divvying up of evidential burdens, evolutionary biology teaches that within biology the burden of evidence forever remains on those who want to deny the adequacy of material mechanisms. In fact, evolutionary biology maintains that design is and always will be superfluous as a causal factor in accounting for biological complexity. The only way actually to substantiate this claim, however, is to provide detailed, testable accounts of how material mechanisms might actually explain the various forms of biological complexity. Now, if for representative instances of biological complexity such accounts could readily be produced, intelligent design would drop out of scientific discussion. Occam's razor, by proscribing superfluous causes, would in that case finish off intelligent design quite nicely.

But that hasn't happened. Why not? The reason is that there are entire classes of complex biological systems for which evolutionary biology lacks detailed, testable accounts of how such systems could have emerged. To see what's at stake, consider how biologists propose to explain the emergence of the bacterial flagellum, a molecular machine that has become the mascot of the intelligent design movement.

In public lectures Harvard biologist Howard Berg calls the bacterial flagellum "the most efficient machine in the universe." The flagellum is a nano-engineered bidirectional motor-driven propeller on the backs of certain bacteria. It spins at tens of thousands of rpm, can change direction in a quarter turn, and propels a bacterium through its watery environment. The intricate machinery in this molecular machine—including a rotor, a stator, O-rings, bushings, and a drive shaft—requires the coordinated interaction of at least forty complex proteins and the absence of any one of these proteins would result in the complete loss of machine function. According to evolutionary biology it had to emerge via some material mechanism(s). Fine, but how?

The usual story is that the flagellum is composed of parts that previously were targeted for different uses and that natural selection then co-opted to form a flagellum. This seems reasonable until we try to fill in the details. The only well-documented examples that we have of successful co-option come from human engineering. For instance, an electrical engineer might co-opt components from a microwave oven, a radio, and a computer screen to form a working television. But in that case, we have an intelligent agent who knows all about electrical gadgets and about televisions in particular.

But natural selection doesn't know a thing about bacterial flagella. So how is natural selection going to take extant protein parts and co-opt them to form a flagellum? The problem is that natural selection can only select for preexisting function. It can, for instance, select for larger finch beaks when the available nuts are harder to open. Here the finch beak is already in place and natural selection merely enhances its present functionality. Natural selection might even adapt a preexisting structure to a new function; for example, it might start with finch beaks adapted to opening nuts and end with beaks adapted to eating insects.

But for co-option to result in a structure like the bacterial flagellum, we are not talking about enhancing the function of an existing structure or reassigning an existing structure to a different function, but reassigning multiple structures previously targeted for different functions to a novel structure exhibiting a novel function. Even the simplest bacterial flagellum is, as machines go, vastly complex.

The only way for natural selection to form such a structure by co-option, then, is for natural selection gradually to enfold existing protein parts into evolving structures whose functions co-evolve with the structures. To see what's at stake, imagine the evolution of a five-part mousetrap (consisting of a platform, spring, hammer, holding bar, and catch): it starts as a doorstop (thus consisting merely of the platform), then evolves into a tie-clip (by attaching the spring and hammer to the platform), and finally becomes a full mousetrap (by also including the holding bar and catch).

Kenneth Miller, a biologist on the faculty of Brown University and one of America's most visible critics of intelligent design, finds such scenarios not only completely plausible but also deeply relevant to biology. In fact, at public discussion about intelligent design, he regularly sports a modified mousetrap cum tie-clip. Notwithstanding, intelligent design proponents regard such scenarios as rubbish.

Here's why. First, in such scenarios the hand of human design and intention meddles everywhere. Evolutionary biologists assure us that eventually they will discover just how the evolutionary process can take the right and needed steps without the meddling hand of design. All such assurances, however, presuppose that intelligence is dispensable in explaining biological complexity. Yet the only evidence we have of successful co-option comes from engineering and confirms that intelligence is indispensable in explaining complex structures like the mousetrap and, by implication, the bacterial flagellum. Intelligence is known to have the causal power to produce such structures. We're still waiting for the promised material mechanisms.

The other reason design theorists are less than impressed with co-option concerns an inherent limitation of the Darwinian mechanism. The whole point of the Darwinian selection mechanism is that one can get from anywhere in biological configuration space to anywhere else provided one can take small steps. How small? Small enough that they are reasonably probable. But what guarantee is there that a sequence of baby-steps connects any two points in configuration space?

The problem is not simply one of connectivity. For the Darwinian selection mechanism to connect point A to point B in biological configuration space, it is not enough that there merely exist a sequence of baby-steps connecting the two. In addition, each baby-step needs in some sense to be "successful." In biological terms, each step requires an increase in fitness as measured in terms of survival and reproduction. Natural selection, after all, is the motive force behind each baby-step, and selection only selects what is advantageous to the organism. Thus, for the Darwinian mechanism to connect two organisms, there must be a sequence of successful baby-steps connecting the two.

Richard Dawkins (1996) compares the emergence of biological complexity to climbing a mountain. He calls it Mount Improbable because if you had to get all the way to the top in one fell swoop (that is, achieve a massive increase in biological complexity all at once), it would be highly improbable. But does Mount Improbable have to be scaled in one leap? Darwinism purports to show how Mount Improbable can be scaled in small incremental steps. Thus, according to Dawkins, Mount Improbable always has a gradual serpentine path leading to the top that can be traversed in baby-steps. But such a claim requires verification. It might be a fact about nature that Mount Improbable is sheer on all sides and getting to the top from the bottom via baby-steps is effectively impossible. A gap like that would reside in nature herself and not in our knowledge of nature (it would not, in other words, constitute a god-of-the-gaps).

Consequently, it is not enough merely to presuppose that a fitness-increasing sequence of baby steps connects two biological systems—it must be demonstrated. For instance, it is not enough to point out that some genes for the bacterial flagellum are the same as those for a type III secretory system (a type of pump) and then take that as evidence that one was co-opted from the other. Anybody can arrange complex systems in series based on some criterion of similarity. But such series do nothing to establish whether the end evolved in a Darwinian fashion from the beginning unless each step in the series can be specified, the probability of each step can be quantified, the probability at each step turns out to be reasonably large, and each step constitutes an advantage to the organism (in particular, viability of the whole organism must at all times be preserved). Only then do we have a mechanistic explanation (in Darwinian terms) of how one system arose from another.

Convinced that the Darwinian mechanism must be capable of doing such evolutionary design work, evolutionary biologists rarely ask what the concrete evidence for such a sequence of successful baby-steps is; much less do they attempt to quantify the probabilities involved. I attempt that in chapter five of my book *No Free Lunch*. There I lay out techniques for assessing the probabilistic hurdles that the Darwinian mechanism faces in trying to account for complex biological structures like the bacterial flagellum. The probabilities I calculate—and I try to be conservative—are horrendous and render natural selection utterly implausible as a mechanism for generating the flagellum and structures like it. If I'm right and the probabilities really are horrendous, then the bacterial flagellum exhibits specified complexity. Furthermore, if specified complexity is a reliable marker of intelligent agency, then systems like the bacterial flagellum bespeak intelligent design and are not solely the effect of material mechanisms.

3. The Argument-from-Ignorance Objection

It's here that critics of intelligent design raise the argument-from-ignorance objection. Critics charge that intelligent design is based on a purely negative form of argumentation. Accordingly, everything depends on establishing that the origin of certain biological systems defies naturalistic explanation. Once this negation is in hand, intelligent design is said to flip-flop, illegitimately transforming this negation into the affirmation that these systems therefore had to be designed. Thus proponents of intelligent design are supposed to be guilty of reasoning directly from the premise "No one has figured out how the flagellum arose" to the conclusion "It must have been designed."

Kenneth Miller (2004), for instance, makes this charge. Miller, despite a long exposure to intelligent design thinkers and writings, continually misses a crucial connecting link in the argument. Let me therefore spell out the premises of the argument as well as its conclusion. Premise 1: Certain biological systems exhibit specified complexity. Premise 2: Darwinians have no detailed, testable proposals for how biological systems with that feature originated. Premise 3: We know, and this is the crucial connecting premise, that intelligent agency has the causal power to produce systems that exhibit specified complexity. (For instance, many human artifacts exhibit specified complexity.) Conclusion: Therefore, biological systems that exhibit specified complexity are likely to be designed. Proponents of intelligent design, in attributing design to systems that exhibit specified complexity, are simply doing what scientists do generally, which is attempt to formulate a causally adequate explanation for the phenomenon in question.

To attribute specified complexity to a biological system requires an eliminative induction. Eliminative inductions argue for the truth of a proposition by arguing that competitors to that proposition are false. (Contrast this with Popperian falsification, where propositions are corroborated to the degree that they successfully withstand attempts to falsify them.) Provided the proposition together with its competitors form a mutually exclusive and exhaustive class, eliminating all the competitors entails that the proposition is true. (Recall Sherlock Holmes's famous dictum: "When you have eliminated the impossible, whatever remains, however improbable, must be the truth.") This is the ideal case, in which eliminative inductions in fact become deductions. The problem is that in practice we don't have a neat ordering of competitors that can then all be knocked down with a few straightforward and judicious blows (like pins in a bowling alley). In *Bayes or Bust*, philosopher of science John Earman (1992, 165) puts it this way:

> The eliminative inductivist [seems to be] in a position analogous to that of Zeno's archer whose arrow can never reach the target, for faced with an infinite number of hypotheses, he can eliminate one, then two, then three, etc., but no matter how long he labors, he will never get down to just one. Indeed, it is as if the arrow never gets half way, or a quarter way, etc. to the target, since however long the eliminativist labors, he will always be faced with an infinite list [of remaining hypotheses to eliminate].

Earman offers these remarks in a chapter titled "A Plea for Eliminative Induction." He himself thinks there is a legitimate and necessary place for eliminative induction in scientific practice. What, then, does he make of this criticism? Here is how he handles it (Earman 1992, 165):

> My response on behalf of the eliminativist has two parts. (1) Elimination need not proceed in such a plodding fashion, for the alternatives may be so ordered that an infinite number can be eliminated in one blow. (2) Even if we never get down to a single hypothesis, progress occurs if we succeed in eliminating finite or infinite chunks of the possibility space. This presupposes, of course, that we have some kind of measure, or at least topology, on the space of possibilities.

To this Earman (1992, 177) adds that eliminative inductions are typically *local inductions*. For such inductions there is no pretense of considering all logically possible hypotheses. Rather, there is tacit agreement on the explanatory domain of the hypotheses as well as on what auxiliary hypotheses may be used in constructing explanations.

That's why intelligent agency having the causal power to produce systems that exhibit specified complexity is such an important premise in eliminative inductions that attempt to infer biological design. Let's even give this premise a name: *the can-do premise* (because we know that designers can do it, that is, generate specified complexity). Precisely because intelligent agency has the causal power to generate specified complexity, there is no need to give equal weight to every conceivable naturalistic hypothesis or to wade interminably through the never-ending list of detail-free Darwinian stories, none of which has ever given any evidence of actually elucidating biological systems that exhibit specified complexity. If you don't believe me on this point, listen to biologist Lynn Margulis (2002, 103): "Like a sugary snack that temporarily satisfies our appetite but deprives us of more nutritious foods, neo-Darwinism sates intellectual curiosity with abstractions bereft of actual details—whether metabolic, biochemical , ecological, or of natural history."

The can-do premise turns an eliminative induction based on specified complexity into a local induction that can legitimately infer design. Too often specified complexity is charged with underwriting a purely negative form of argumentation. But that charge is not accurate. The argument for the specified complexity of the bacterial flagellum, for instance, makes a positive contribution to our understanding of the limitations that natural mechanisms face in trying to account for it. Eliminative inductions, like all inductions and indeed all scientific claims, are fallible. But they need a place in science. To refuse them, as evolutionary biology tacitly does by rejecting specified complexity as a criterion for detecting design, does not keep science safe from disreputable influences but instead undermines scientific inquiry itself.

The way things stand now, evolutionary biology has in place procedural rules that allow intelligent design only to fail but not to succeed. If evolutionary biologists can discover or construct detailed, testable, indirect Darwinian pathways that account for complex biological systems like the bacterial flagellum, then intelligent design will rightly fail. On the other hand, evolutionary biology makes it effectively impossible for intelligent design to succeed. According to evolutionary biology, intelligent design has only one way to succeed, namely, by showing that complex specified biological structures could not have evolved via any material mechanism. In other words, so long as some unknown material mechanism might have evolved the structure in question, intelligent design is proscribed.

Evolutionary theory is thereby rendered immune to disconfirmation in principle because the universe of unknown material mechanisms can never be exhausted. Indeed, the evolutionist has no burden of evidence. But notice that there’s no logically consistent reason evolutionists shouldn't hold themselves to the same ridiculous burden of evidence. Indeed, if any side should have to shoulder that impractical burden, history tells it should be the evolutionary naturalists. Why? They are in the extreme, historical minority in denying that biological systems are designed. More significantly, they themselves admit that biological systems appear on their face to belong to that known class of things that are intelligently designed. For instance, Francis Crick (1988, 138) writes, "Biologists must constantly keep in mind that what they see was not designed, but rather evolved." Oxford's very own Richard Dawkins (1987, 1) agrees. On page one of *The Blind Watchmaker* he writes, "Biology is the study of complicated things that give the appearance of having been designed for a purpose," whereupon he requires an additional three-hundred pages to show that the appearance of design in biology is only an appearance.

If a creature looks like a dog, smells like a dog, barks like a dog, feels like a dog, and pants like a dog, the burden of evidence lies with the person insisting the creature isn't a dog. The same goes for incredibly intricate machines like the bacterial flagellum—the burden of evidence is on those who want to deny its design. And yet you won't find Darwinists rolling up their sleeves and trying to eliminate every imaginable and as yet unimagined intelligent design scenario, pleading for patience while they work their way through an infinite set of possibilities. Instead, they spuriously shift the burden of evidence entirely to the skeptic of naturalistic evolution, insisting that such skeptics establish a universal negative not merely by an eliminative induction (such inductions are usually local and constrained) but by an exhaustive search and elimination of all conceivable naturalistic possibilities—however remote, however unfounded, however unsupported by evidence. That is not how science is supposed to work.

Science is supposed to give the full range of possible explanations a fair chance to succeed. That's not to say that anything goes; but it is to say that anything might go. In particular, science may not by a priori fiat rule out logical possibilities. Evolutionary biology, by limiting itself exclusively to material mechanisms, has settled in advance which biological explanations are true apart from any consideration of empirical evidence. This is arm-chair philosophy. Intelligent design may not be correct. But the only way we could discover that is by admitting design as a real possibility, not by ruling it out a priori. Darwin (1859, 2) himself would have agreed. In the *Origin of Species* he wrote, "A fair result can be obtained only by fully stating and balancing the facts and arguments on both sides of each question."

4. Potential Impact of Intelligent Design

Until now, I've focused on the logical coherence of design-detecting criteria, their applicability to biology, and their ability decisively to preclude material mechanisms. Proponents of intelligent design have made solid progress on these questions. Even the scientific mainstream acknowledges as much. Take Paul Davies, a prolific science writer and well respected physicist in his own right. Commenting on my book *The Design Inference*, Davies remarks, "Dembski's attempt to quantify design, or provide mathematical criteria for design, is extremely useful. I'm concerned that the suspicion of a hidden agenda is going to prevent that sort of work from receiving the recognition it deserves." (quoted in Witham 2003, 149). Or consider cell biologist Franklin Harold

(2001, 205), who, despite having doubts about intelligent design, nonetheless remarks, "We must concede that there are presently no detailed Darwinian accounts of the evolution of any biochemical or cellular system, only a variety of wishful speculations."

In my experience, plenty of scientists are intrigued with intelligent design. Yet at the same time, few see how they can contribute to it scientifically. Take Francis Collins, head of the Human Genome Project. As a Christian believer, he is committed to design in some broad sense. Yet, at a meeting of the American Scientific Affiliation (Pepperdine University, August 2002) he worried about what he called intelligent design's "lack of a plan for experimental verification." Such worries are unfounded. Intelligent design does have a plan for experimental verification. In concluding this paper, let me sketch a few salient components of that plan bullet-point fashion.

- *Methods of Design Detection*. Methods of design detection are widely employed in various special sciences (e.g., archeology, cryptography, and the Search for Extraterrestrial Intelligence or SETI). Design theorists investigate the scope and validity of such methods.

- *Biological Information*. What is the nature of biological information? How do function and fitness relate to it? What are the obstacles that face material mechanisms in attempting to generate biological information? What are the theoretical and empirical grounds for thinking that intelligence is indispensable to the origin of biological information? Design theorists see specified complexity as the key to understanding biological information.

- *Evolvability*. Evolutionary biology's preferred research strategy consists in taking distinct biological systems and finding similarities that might be the result of a common evolutionary ancestor. Intelligent design, by contrast, focuses on a different strategy, namely, taking individual biological systems and perturbing them (both intelligently and randomly) to see how much the systems can evolve. Within this latter research strategy, limitations on evolvability by material mechanisms constitute indirect confirmation of design.

- *Evolutionary Computation*. Organisms employ evolutionary computation to solve many of the tasks of living (e.g., the immune system in vertebrates). But does this show that organisms originate through some form of evolutionary computation (as through a Darwinian evolutionary process)? Are GPGAs (General Purpose Genetic Algorithms) like the immune system designed or the result of evolutionary computation? Need these be mutually exclusive? Evolutionary computation is something that organisms do, but it is also used to account for the origination of certain features of organisms. Design theorists explore the relationship between these two types of evolutionary computation as well as any design intrinsic to them. One aspect of this research is writing and running computer simulations that investigate the scope and limits of evolutionary computation. One such simulation is the MESA program (Monotonic Evolutionary Simulation Algorithm) due to Micah Sparacio, John Bracht, and me. It is available online at www.iscid.org/mesa.

- *Technological Evolution (TRIZ)*. The only well-documented example we have of the evolution of complex multipart integrated functional systems (as we see in biology) is the technological evolution of human inventions. In the second half of the twentieth century, Russian scientists and engineers studied hundreds of thousands of patents to determine how technologies evolve. They codified their findings in a theory to which they gave the acronym TRIZ, which in English translates to Theory of Inventive Problem Solving (Savransky 2000). The picture of technological evolution that emerges out of TRIZ parallels remarkably the history of life as we see it in the fossil record and includes the following:

(1) New technologies (cf. major groups like phyla and classes) emerge suddenly as solutions to *inventive problems*. Such solutions require major conceptual leaps (i.e., design). As soon as a useful new technology is developed, it is applied immediately and as widely as possible (cf. convergent evolution).

(2) Existing technologies (cf. species and genera) can, by contrast, be modified by trial-and-error tinkering (cf. Darwinian evolution), which amounts to solving *routine problems* rather than inventive problems. The distinction between routine and inventive problems is central to TRIZ. In biology, Michael Behe's (1996) notion of irreducible complexity suggests one way of making the analytic cut between these types of problems. Are there other ways?

(3) Technologies approach ideality (cf. local optimization by means of natural selection) and thereafter tend not change (cf. stasis).

(4) New technologies, by supplanting old technologies, can upset the ideality and stasis of the old technologies, thus forcing them to evolve in new directions (requiring the solution of new inventive problems, as in an arms race) or by driving them to extinction.

In thus mapping TRIZ onto biological evolution, I need here to add a footnote. Most design critics, by conflating intelligent design with creationism, see intelligent design as committed to a designer who always designs from scratch and has to get everything right the first time. TRIZ, by contrast, bespeaks an evolutionary process that as much as possible takes advantage of existing designs but then at key moments requires a conceptual breakthrough to move the process of technological evolution along. On this view, the process of technological evolution is itself designed. What's more, within that process, designing intelligences interact with natural forces. Does this mean that a designing intelligence is making things up as it goes along? Not necessarily. The conceptual breakthroughs needed to drive technological evolution can be programmed from the start. And what about suboptimal and dysteleological design? These can be explained in part as the result of natural forces subverting an original design plan. Teasing apart the effects of intelligence from natural forces thus becomes a key research question for a TRIZ approach to intelligent design.

- *Strong Irreducible Complexity of Molecular Machines and Metabolic Pathways*. For certain enzymes (which are themselves highly complicated molecular structures) and metabolic pathways (i.e., systems of enzymes where one enzyme passes off its product to the next, as in a production line), *simplification leads not to different functions but to the complete absence of all biological function*. Systems with this feature exhibit a strengthened form of what Michael Behe (1996) calls irreducible complexity (for Behe simplification of an irreducibly complex system leads to loss of a given function but not necessarily to the loss of all biological function). *Strong irreducible complexity*, as it may be called, entails that no Darwinian account could in principle be given for the emergence of such systems. Theodosius Dobzhansky, one of the founders of the neo-Darwinian synthesis, once remarked that to talk about prebiotic natural selection is a contradiction in terms—the idea being that selection could only select for things that are already functional. Current research on strong irreducible complexity seeks out and analyzes biological systems that cannot in principle be grist for selection's mill. If successful, this research, which is still at the early stages, would imply the unraveling of molecular Darwinism.

- *Natural and Artificial Biological Design (Especially Bioterrorist Genetic Engineering)*. We are on the cusp of a bioengineering revolution whose fallout is likely to include bioterrorism. Thus we can expect to see *bioterror forensics* emerge as a practical scientific discipline. How will such forensic experts distinguish the terrorists' biological designs from naturally occurring biological designs?

- *Design of the Environment and Ecological Fine-Tuning*. The idea that ecosystems are fine-tuned to support a harmonious balance of plant and animal life is old. How does this balance come about. Is it the result of blind Darwinian forces competing with one another and leading to a stable equilibrium? Or is there design built into such ecosystems? Can such ecosystems be improved through conscious design or is "monkeying" with such systems invariably counterproductive? Design-theoretic research promises to become a significant factor in scientific debates over the environment.

- *Steganographic Layering of Biological Information*. Steganography belongs to the field of digital data embedding technologies (DDET), which also include information hiding, steganalysis, watermarking, embedded data extraction, and digital data forensics. Steganography seeks efficient (high data rate) and robust (insensitive to common distortions) algorithms that can embed a high volume of hidden message bits within a cover message (typically imagery, video, or audio) without their presence being detected. Conversely, steganalysis seeks statistical tests that will detect the presence of steganography in a cover message. Key bioinformatics research question: To what degree do biological systems incorporate steganography, and if so, is biosteganography demonstrably designed?

- *Cosmological Fine-Tuning and Anthropic Coincidences*. Although this is a well worn area of study, there are some new developments here. Guillermo Gonzalez, an astrophysicist at Iowa State University, and Jay Richards, a philosopher with Seattle's Discovery Institute, have a forthcoming book titled *The Privileged Planet* (along with a video based on the book) in which they make a case for planet Earth as intelligently designed not only for life but also for scientific discovery. In other words, they argue that our world is designed to facilitate the scientific discovery of its own design. Aspects of Gonzalez's work in this area have been featured in the cover story of the October 2001 *Scientific American*.

- *Astrobiology, SETI, and the Search for a General Biology*. What might life on other planets look like? Is it realistic to think that there is life, and even conscious life, on other planets? What are the defining features that any material system must possess to be alive? How simple can a material system be and still be alive (John von Neumann posed this question over half a century ago in the context of cellular automata)? Insofar as such systems display intelligent behavior, must that intelligence be derived entirely from its material constitution or can it transcend yet nevertheless guide its behavior (cf. the mechanism vs. vitalism debate)? Is there a testable way to decide this last question? How, if at all, does quantum mechanics challenge a purely mechanistic conception of life? Design theorists are starting to investigate these questions.

- *Consciousness, Free Will, and Mind-Brain Studies*. Is conscious will an illusion—we think that we have acted freely and deliberately toward some end, but in fact our brains acted on their own and then deceived us into thinking that we acted deliberately. This is the majority position in the cognitive neuroscience community, and a recent book makes just that claim in its title: *The Illusion of Conscious Will*, by Harvard psychologist Daniel

Wegner. But there is now growing evidence that consciousness is not reducible to material processes of the brain and that free will can do better than soft determinism. Jeffrey Schwartz at UCLA along with quantum physicist Henry Stapp at the Lawrence Berkeley National Laboratory are two of the key researchers presently providing experimental and theoretical support for the irreducibility of mind to brain (see Schwartz's book *The Mind and the Brain: Neuroplasticity and the Power of Mental Force*).

- *Autonomy vs. Guidance*. Many scientists worry that intelligent design attempts to usurp nature's autonomy. But that is not the case. Intelligent design is attempting to restore a proper balance between nature's autonomy and teleologic guidance. Prior to the rise of modern science all the emphasis was on teleologic guidance (typically in the form of divine design). Now the pendulum has swung to the opposite extreme, and all the emphasis is on nature's autonomy (an absolute autonomy that excludes design). Where is the point of balance that properly respects both, and in which design becomes empirically evident? The search for that balance-point underlies all design-theoretic research. It's not all design or all nature but a synergy of the two. Unpacking that synergy is the intelligent design research program in a nutshell.

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