

# **Bits, Bytes and Biology: What Evolutionary Algorithms (Don't) Teach Us About Biology**

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*Far from constituting a devastating critique of irreducible complexity, the evolutionary algorithm, Avida, is a flawed effort that bears little relevance to the biological world. In their haste to affirm the Darwinian creation story, the Avida authors seem oblivious to, or conveniently ignore, the fact that they have incorporated as premises the very conclusions they are trying to reach. Such efforts are at best misleading, at worst deceptive. Ironically, the main piece of data obtained by the Avida researchers that is not based on circular evolutionary assumptions, upon closer inspection supports, rather than refutes, Behe's notion of irreducible complexity.*

Computer simulation has become an ever increasing aspect of modern scientific research. From early solar system models to more complicated (and as yet, less reliable) weather simulations, scientists are turning to computer programs as powerful tools in understanding and predicting the natural world around us. Computer simulations allow researchers to cheaply, quickly, and repeatedly test predictions and models. Unfortunately, the old moniker GIGO (garbage in, garbage out) still holds ominous sway, and creating accurate models, particularly of complex systems, remains notoriously difficult.

Evolutionary biologists, not wanting to be left out of the fun have joined their brethren in physics and chemistry in preparing computer programs that attempt to simulate biological evolution. Such programs, or "evolutionary algorithms," as they have come to be called, have been on the scene for some time and occasionally yield interesting results. What over-eager evolutionary biologists claim the data show and what the data in fact show, however, often lie miles apart, with only the researchers' indefatigable faith in the evolutionary mechanism able to bridge the chasm between fact and proclamation.

## **Avida**

One of the more widely discussed evolutionary algorithms in recent months has been the program Avida.<sup>1</sup> The Avida researchers described their results in the May 2003 issue of *Nature*, in an article entitled "The Evolutionary Origin of Complex Features." The named authors of the study are Richard Lenski, Charles Ofria, Robert Pennock and Christoph Adami.

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<sup>1</sup> Lenski, et al., "The Evolutionary Origin of Complex Features," *Nature* 423, May 8, 2003, pp. 139-44.

The publication of the Avida research was just what the doctor ordered for evolutionary theorists, still smarting from Michael Behe's publication several years earlier of *Darwin's Black Box*, and the recent video documentary *Unlocking the Mystery of Life*. In critiquing *Unlocking the Mystery of Life*, on the NCSE's unabashedly pro-evolution website, Andrea Bottaro triumphantly proclaimed that Avida had "delivered a fatal blow [to irreducible complexity] in the prestigious science journal *Nature*."<sup>2</sup>

Further, in the introduction to the Avida article, it is suggested that Avida demonstrates "how complex functions can originate by random mutation and natural selection." Indeed, in reading the Avida article, the uninitiated reader might be impressed with the research results amassed in support of the evolutionary story.

The thoughtful skeptic, however, is not so easily swayed, and might be wary of the very idea that putting together what is by all accounts a rather simple computer program could single-handedly confirm the truth of Darwin's "slight successive changes" plus natural selection. A number of individuals have challenged the accuracy of Avida's algorithm and its applicability to real life,<sup>3</sup> while others have disputed the underlying assumptions.<sup>4</sup> Nevertheless, the Avida authors are convinced that they have proven the essential truth of Darwin's theory<sup>5</sup> and thus press on with their optimistic pronouncements.

My purpose in this brief essay is not to dispute the accuracy of the Avida algorithm at a computational level, nor to quibble over the number of digital "organisms" employed in each generation, the types of environments in which they operate and so forth, though no doubt reasonable concerns could be raised in each case. Rather, my purpose is to explicitly lay out the underlying logic employed by the researchers in their efforts.

Once we parse through the underlying rhetoric and apply a few basic principles of logic to Avida, we will see that not only does Avida not deliver a "fatal blow" to the concept of irreducible complexity, but that Avida is logically incapable of challenging irreducible complexity.<sup>6</sup> While we mustn't fault the researchers for working on algorithms such as

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<sup>2</sup> I have provided a detailed response to the NCSE's critique of *Unlocking the Mystery of Life* on my website entitled "No Mystery in the NCSE," retrieved from [http://www.evolutiondebate.info/No\\_Mystery\\_in\\_the\\_NCSE.htm](http://www.evolutiondebate.info/No_Mystery_in_the_NCSE.htm) (last accessed October 28, 2004). Despite promises to the contrary, the NCSE has never provided any meaningful scientific critique of the arguments raised in *Unlocking the Mystery of Life*.

<sup>3</sup> See, for example, the online discussion entitled "Evaluation of Neo-Darwinian Theory with Avida Simulations" at the International Society for Information, Complexity and Design website, retrieved from [http://www.iscid.org/boards/ubb-get\\_topic-f-6-t-000532-p-3.html](http://www.iscid.org/boards/ubb-get_topic-f-6-t-000532-p-3.html) (last accessed October 28, 2004).

<sup>4</sup> See, for example, William Dembski's remarks regarding Avida in "The Myth of Darwinism," Introduction to *Uncommon Dissent*, ISI Books, Wilmington, Delaware, 2004, p. xxix.

<sup>5</sup> "Our experiments demonstrate the validity of the hypothesis, first articulated by Darwin . . . that complex features generally evolve by modifying existing structures and functions." Lenski, et al., p. 143.

<sup>6</sup> As used in this essay "irreducible complexity" matches the irreducible complexity initially proposed by Behe and refined by Dembski, meaning that there is no cumulative pathway to such complexity. I have

Avida (we are all free to dabble with computer programs), the authors' failure to appreciate their own underlying assumptions, coupled with their enthusiasm in proving Darwin's theory, leads the authors to arrive at conclusions that not only are unsupported by the data, but are bordering on deceptive.

## Background

The authors begin by declaring their allegiance to Darwinian evolution in the following terms: "Charles Darwin's theory of evolution, including its intertwined hypotheses of descent with modification and adaptation by natural selection, is widely regarded as one of the greatest scientific achievements of all time." While such sentiments might cause the careful observer to question the authors' impartiality in evaluating the merits of Darwin's theory, such statements no doubt help to move papers through the review process at *Nature*.<sup>7</sup>

The authors declare as their principal goal, the determination of whether complex features can evolve by a process of mutations and natural selection. In essence, the authors are attempting to challenge the concept of irreducible complexity popularized by Michael Behe in his 1996 best seller, *Darwin's Black Box*. Let us examine how the authors conclude that their evolutionary program dispenses with the notion of irreducible complexity.

In creating Avida, the researchers set up a system of functional operators which serve as fitness characteristics. By executing certain functional operators, "organisms" are rewarded with additional energy, which allows them – under traditional Neo-Darwinian doctrine – to reproduce faster, which, notwithstanding contrary evidence, is for the Neo-Darwinist the great and ultimate goal of all creatures biological.

The authors make liberal use of biological terminology in describing their computer program, referring to the set of virtual CPU stacks and registers as "organisms," the instruction sets as "genomes," the resultant organisms as "phenotypes," and the various sets of reward parameters as different selective "environments." While such terminology may be justified due to the authors' goal of analogizing to biological systems, one cannot help but wonder if the Avida results might seem somewhat less applicable to biology without all the biological terminology.

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shown in my [article](#) "Irreducible Complexity Reduced: An Integrated Approach to the Complexity Space," (see [www.evolutiondebate.info](http://www.evolutiondebate.info)) that this is not a logical requirement of the concept of irreducible complexity, and I term Behe's and Dembski's approach "per se irreducible complexity." Avida targets this per se irreducible complexity, and it is sufficient for our present purposes.

<sup>7</sup> Having seen similar declarations of evolutionary faith, I am struck with the uncanny similarity to the Soviet-era publication review process. One of the tricks of the trade for getting published in the former Soviet Union was to devote a small portion of one's paper to paying homage to Stalin or Lenin, as well as a declaration of faith in the communist regime. Such statements were, of course, almost always irrelevant to the topic at hand and occasionally even detracted from the scholarly work, but were immensely helpful in getting publications past Soviet censors.

## Evolutionary Assumptions

With that background, let us examine the key assumptions built into Avida:<sup>8</sup>

1. *There is a cumulative pathway to complexity.*

Avida was programmed so that a slight, successive cumulative pathway to the ultimate complex function existed. In other words, the researchers *assumed* that the ultimate complex feature was not irreducibly complex, and wrote their program in such a way as to *guarantee* that it would not be irreducibly complex, before they even ran the very first simulation. Thus, it is deeply troubling to find the authors suggesting that Avida demonstrates that complex systems are not irreducibly complex.

What is more astonishing, is that the authors are aware of their circular reasoning, but blithely dismiss it.<sup>9</sup> In the final discussion section, they state, “Some readers might suggest that we ‘stacked the deck’ by studying the evolution of a complex feature that could be build on simpler functions that were also useful. However, that is precisely what evolutionary theory requires . . .” Say what?? In other words, we have adopted as our premise the very conclusion we are trying to reach. In a particularly Darwinian display of twisted logic, the researchers seem oblivious to the fact that this circular reasoning invalidates their entire conclusion, and cheerfully waive it aside as an inconsequential technicality. At best such an approach manifests questionable judgment, at worst, self-deception.

I should add that on the other side of the coin, if a program were written that had no possible cumulative pathway, then the writers of that program could be fairly accused of assuming up front that the complex feature was irreducibly complex. Thus, evolutionary algorithms seem to be between a rock and a hard spot: assume a cumulative pathway and then you are unable to challenge irreducible complexity; assume there is no cumulative pathway and then you are unable to support irreducible complexity. And herein lies the crux of the matter. Evolutionary algorithms that assume a cumulative or non-cumulative pathway at the outset *simply cannot, by definition, demonstrate whether the complex system is irreducibly complex*. Such algorithms define themselves into irrelevance. The only way to properly assess the likelihood of an evolutionary pathway to a complex system is to actually input the genetic and epigenetic biological parameters. This, unfortunately, is beyond current capability, but will hopefully someday be within our

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<sup>8</sup> I am ignoring for a moment the small number of biological parameters built into Avida regarding population size, mutation rates, deleterious effects, etc. Each of these parameters has also been the subject of some question, but for my purposes, I will focus on the logical assumptions.

<sup>9</sup> Having last week purchased for other reasons, *Uncommon Dissent*, I am gratified to note that Dembski has come to a similar conclusion regarding the circularity of the underlying Avida argument. See reference under footnote 4 above.

grasp. In the meantime, we would do well to question whatever results evolutionary algorithms bring to the table.

2. *Relatively few changes are required to get from the initial organism to the complex feature.*

This is more a question of fact than a logical problem, but it does strain credulity. Are we expected to believe that the distance, say, between Miller's type III secretory system<sup>10</sup> and the bacterial flagellum is slight, or that the formation of the mammalian eye is only as complex as the author's EQU instruction?<sup>11</sup> In fairness, the authors make no direct statement to this effect, but they do throughout their paper refer to "complex" features, which most people in the current evolution debate understand to mean "really complex" – along the lines of the mammalian eye or the bacterial flagellum complex. Indeed, no-one is interested in whether an EQU function can evolve, but rather whether complex biological features can. By claiming to show that complex features can evolve in a Darwinian fashion, the authors are at least implying, if not explicitly stating, that their results might be applicable to truly complex biological systems, like the bacterial flagellum or the mammalian eye. Yet in my estimation the authors' EQU instruction looks more like a minor adaptation than a significant evolutionary change.

3. *There are regular and closely spaced fitness plateaus in proceeding from one function to the next.*

This assumption is based on a rather simplistic view of the fitness landscape. For Darwin, the fitness landscape was essentially level, with "slight successive variations" leading slowly, almost imperceptibly, to new organisms over a flat plain. More recent research suggests that the fitness landscape is more like an expansive valley, interspersed with occasional plateaus that constitute functional organisms. The distance between these plateaus is rarely insignificant and depends on a number of factors, not the least of which is the fact that many biological systems in an organism are closely interconnected and highly interdependent. Thus, it is not enough to simply alter a gene here or a protein there and move toward a new fitness plateau. More often than not, wholesale changes are required, with a myriad of architectural adjustments at numerous levels. Avida, however, proceeds happily from one plateau to another, with the changes in fitness requiring but a small mutation here, a minor tweak or two there. Thus, not only does the researchers' assumed fitness landscape not represent biological reality, but it in fact skews the results toward the very outcome the researchers are trying to reach: the move from plateau to plateau is straightforward and relatively easy.

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<sup>10</sup> I am well aware that the type III secretory system did not likely evolve into the bacterial flagellum (see, e.g., Scott A. Minnich & Stephen C. Meyer, "Genetic Analysis of Coordinate Flagellar and Type III Regulatory Circuits in Pathogenic Bacteria," *Second International Conference on Design & Nature, Rhodes Greece*, September 1, 2004, retrieved from <http://www.discovery.org/scripts/viewDB/filesDB-download.php?id=148> (last accessed October 28, 2004)). However, I mention it because this system continues to be the poster child of evolutionary proponents like Kenneth Miller.

<sup>11</sup> The EQU instruction is Avida's highest level complex feature.

4. *Intermediate steps provide a functional advantage.*

The Avida researchers initially approach the intermediate functions as though there were a beneficial continuum from one function to the next, although it is far from clear that this would be the case in the real world. A large part of evolutionary critics' argument from irreducible complexity is that there is unlikely to be a functional advantage for intermediate steps. What good is a cornea without a lens? What good are a cornea and a lens without the retina? And what good are all of these without an exceedingly complex and interconnected nervous system to carry the information to the brain? This is in fact one of the key areas in question in the debate over irreducible complexity, but the Avida authors simply assume it away.

The researchers were subsequently able to obtain the EQU function in environments where "one or two simpler functions were not rewarded."<sup>12</sup> As a result, the researchers conclude that "neither any particular simpler function nor any pairwise combination of functions was required" to generate EQU.<sup>13</sup>

While at first blush this statement may seem supportive of some unexplained evolutionary mechanism, upon closer inspection it turns out to be more a programming artifact than any revelation about the natural world. In other words, Avida's cumulative pathway to EQU was elastic enough to allow an unrewarded function to be preserved until the organism got lucky enough to mutate a further rewarded function and get back on track to its EQU goal. Certainly, there is some possibility that neutral mutations in nature could hang around pending final assembly of a complex feature, but such an approach takes us completely out of the slight-successive-mutations-preserved-by-natural-selection mode and back into a reliance on pure chance. Thus, this finding is not supportive of the authors' attempt to demonstrate a cumulative pathway, and is not further addressed in the Avida article.

As discussed below on page 7, in the more extreme cases where no intermediate rewards were provided, the populations were not able to stumble upon EQU. Thus, although Avida's programming is fluid enough to allow populations to retain an occasional neutral mutation, as a general matter a step-by-step rewarded pathway appears critical to the researchers' ability to generate EQU.

5. *Each functional advantage is promptly rewarded.*

Even if there is a functional advantage in a theoretical sense, nature does not operate as an infallible computer program, doling out rewards at each turn. Although a particular change might constitute an objective functional advantage, it is still a significant matter to

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<sup>12</sup> Lenski, et al., p. 143.

<sup>13</sup> Ibid.

get the change incorporated into the population. The challenges of reproducing, the numerous vagaries and hazards of nature, all decrease the likelihood of any particular directional change. Furthermore, an advantageous change in one sense can be deleterious in another sense. The tremendous interconnectedness of an organism's biological systems makes incorporating any particular change into the main whole a significant challenge.

One may of course argue that notwithstanding these practical difficulties, we are only talking about successful functional advantages that have already overcome the vagaries of nature and have been successfully incorporated into the organism, and that thus on that definition the Avida assumption is appropriate. However, this begs the entire question. It is entirely an open question whether a particular functional advantage in isolation would be able to integrate successfully into the organismic whole. The Avida researchers, however, take for granted that it will integrate nicely, thank you very much, thus again assuming the necessary point in question at a key juncture. What is needed is an actual analysis of whether a functional advantage in isolation can realistically contribute to overall fitness, not an assumption that it does.

6. *“The benefits increased exponentially with the approximate difficulty of each function.”*<sup>14</sup>

In other words, each step closer to the complexity goal (wait a minute, what is that word “goal” doing in an alleged evolutionary mechanism!) is rewarded in a way that makes that step more advantageous vis-à-vis previous steps. No-one questions that a fully-developed complex feature that has been successfully integrated into an organism under the previous paragraph might provide a survivability advantage. But building and integrating the complex feature is precisely the issue at question in the first place. In nature, would a creature that had developed a cornea and a lens be “exponentially” rewarded toward its “goal” of producing an eye over a creature that had only developed a cornea, if neither creature had a retina? Of course not.

What the Avida authors have done is slip a goal, a design if you will, in through the back door. Rather than turning the organisms loose to stumble upon the ultimate complex system in a realistic environment, the researchers have carefully established a specific pre-determined goal and then incessantly flogged the population up the back of Mount Improbable. This is not an impartial result of simulating anything in the real world. It is the result of *assuming* that each step along the way toward the goal has an increased advantage. Unfortunately, in this regard Avida amounts to little more than a sophisticated version of Dawkins' discredited “methinks it is a weasel” effort, or his biologically problematic musings of 5% of an eye and then 6% of an eye and so on.

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<sup>14</sup> Id., p. 140.

## **Avida's Results**

With the foregoing assumptions built into the Avida program, the researchers cheerfully announce that they have shown that a cumulative pathway to complex systems exists. Sorry to burst any bubbles, but the assumptions discussed above are precisely the key points in question in the debate over irreducible complexity. What the Avida researchers have done is *assume* all of the key evolutionary points at issue. Put another way, if we assume Darwinian evolution is true, then we can demonstrate that it is. Not an impressive result.

But, Anderson, you protest, surely there must be something worthwhile in the Avida study. Yes, in fairness there is one particular piece of information that I find insightful. As discussed previously, while the authors were able to coax organisms to develop the ultimate function when one or two simpler functions were not rewarded, in 50 populations where only the ultimate EQU function was rewarded, none of these populations evolved the ultimate function. The authors note this interesting fact, but mistakenly assume that this result either is an inconsequential side note or is “expected” as a part of evolutionary theory.

However, what this piece of data in fact demonstrates, is that even if there is a guaranteed step-by-step pathway to complex function, unless each step, or at least the vast majority of the steps, along the way are handsomely rewarded in a fashion that drives the organisms toward the ultimate goal, the complex feature cannot be expected to arise in the population. In other words, in addition to a guaranteed step-by-step pathway, it is necessary to have a regular reward system at regular intervals that anticipates the final goal. This foresight is not something that Darwinian evolution can provide even in principle.

Yet isn't this precisely one of Behe's points? Behe's reason for talking about the flagellum or the mammalian eye as challenges to Darwinian evolution is that it is unlikely that there would be handsome rewards for a long chain of intermediate functions. It is worth asking again, what good is a cornea without a lens? What good are a cornea and a lens without the retina? In most complex biological systems it is unclear what functional advantage a few spare parts of the system might endow upon the organism. And it strains reason to suggest that the organism would be rewarded “exponentially” for exercising its forethought in accumulating each part until the final system eventually comes together.

## **Conclusion**

The evolutionary algorithm, Avida, like most evolutionary algorithms, utterly fails to support Darwinian evolutionary ideas regarding the development of complex biological features. In addition to significant questions about its relevance to actual biology, Avida fails as a matter of logic to challenge the concept of irreducible complexity. In attempting to show how complex features can originate by random mutation and natural selection, the authors have incorporated as premises all of the principal conclusions they are trying to reach. Such efforts are at best an exercise in irrelevance, at worst, an



exercise in self-deception. Similar efforts in the future might be appropriately submitted to an amateur computing journal, but bear little relevance to the origin and development of life on the Earth.

Ironically, the main result the researchers obtained that was not directly dependent upon evolutionary presuppositions, is that a complex feature (even a relatively modest one in this case), is not likely to evolve unless there is a handsome reward at regular steps along the way. For the numerous complex features in the biological world that require all parts to be in place to provide a functional advantage, Darwin's reward-based natural selection hypotheses is thus of no assistance, and we are left to rely upon brute chance and statistical probabilities. In this regard, the Avida result underscores the unlikelihood of a population ever stumbling upon a complex feature. Therefore, one of the main pieces of objective data flowing from the Avida study seems to confirm, rather than refute, Behe's notion of irreducible complexity.

In the future, Behe and other proponents of irreducible complexity may wish to consider citing the Avida study in their support! □