Artificial Intelligence and Intelligent Design

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Abstract

Interlocutors in the debate over Intelligent Design frequently talk past each other, failing to understand why their arguments are not compelling to the other side. We bring a few insights and analogies from the field of computer science to the playing field, in hopes of making the discussion more clear and constructive. In particular, we introduce the imagery of local optima as a means of quickly visualizing the limits of evolution and the problem of irreducible complexity. Emphasizing a method of constructive, respectful dialogue between world views, we take inspiration from Bayesian statistics and use graphical models to diagram the hermeneutic cycle of the different camps – a poor understanding of which frequently serves to aggravate an already palpable aversion to dialogue. We then consider the role that observations and computer simulations of emergent complexity can play in confounding attempts to infer design from apparent irreducible complexity, and finally discuss the possibility that computer simulations of evolutionary processes can serve as a proxy for measuring our understanding of evolutionary mechanisms. We conclude that, while Intelligent Design can form a valid part of a religious world view founded on personal experience or some other evidence, the current state of its observations are sufficient neither to prove the existence of a designer nor to disprove evolution.

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1. Introduction

“The general form of propositions is: This is how things are.” – That is the kind of proposition one repeats to himself countless times. One thinks that one is tracing nature over and over again, and one is merely tracing round the frame through which we look at it. – Ludwig Wittgenstein [1]

The creation-evolution debate is loud, and always has been. With a few notable exceptions, there is more posturing and rhetoric than there is communication and dialogue. The clarity to be found on either side is often a false one, used to entice audiences to conviction via a naively black and white view of the highly complex reality of primary literature and scientific arcana.

As a computer scientist studying artificial intelligence and evolutionary computation, I am very interested in both the nature of clear and precise reasoning, and in the limits of evolutionary processes’ ability to solve complex problems. This essay, then, is an attempt to bring, via the occasional insight from computer science, some precision to the discussion surrounding Intelligent Design (ID) and irreducible complexity, which has been a popular and highly charged topic amongst American Christians for the past decade or so.

Beginning with section 2, we use the (somewhat imperfect) caricature of evolution as an optimization algorithm to succinctly and visually capture the limits of evolutionary processes in the concept of local optima. From here the question posed by Intelligent Design is whether there are cases observed in nature where an evolutionary mechanism is insufficient to plausibly explain the origin of a system. One candidate class of such violations is irreducible complexity, and ID proponent William Dembski aims to offer a set of scientific criteria, related to the tools of information theory, by which irreducible complexity can be identified.

Exactly where the limits of natural evolutionary mechanisms lie, however, are not precisely known, and the two camps disagree vehemently on what an “adequate argument” regarding their violation (or not) should look like. In section 3, we explore how this communication block stems in part from differences in hermeneutic cycle or world view which affect each party’s criteria for the plausibility of arguments, and which are often difficult for interlocutors to make clear (thus the resort to polemic). Drawing from theologian Miroslav’s Volf’s Christ-centered philosophy of a sympathetic “double vision” ((60)) and Thomas Kuhn’s holistic view of science ([34]), we adopt the strategy of approaching the Other respectfully, and attempting to make the hermeneutic elements of scientific interpretation explicit and understood by both parties. To achieve this, we draw inspiration from computer science to utilize a (slightly adulterated) form of Bayesian belief networks to diagram the relationships between evidence.

Once this epistemological context is established, Section 4 addresses a central aim of this paper: introducing the reader to the idea of emergent complexity. In computer simulations and real-world systems, artifacts that appear complex to the observer can be generated with a surprisingly small amount of information. While the extent of emergent complexity’s role in biology is still being elucidated, it is a phenomenon that must be taken seriously and controlled for when arguing that irreducible complexity has been observed. This is especially the case in macroscopic structures such as the eye, which come about via extended developmental processes. Nevertheless, many exponents of irreducible complexity either ignore or dismiss the notion of emergence with inadequate discussion. The idea of emergent complexity commands a great deal of currency across myriad scientific fields, and its neglect significantly undermines the case for Intelligent Design, which must deal competently with alternative hypotheses in order to legitimize itself.

Finally, the fact of the matter is that, even while they believe firmly that Darwin provides an accurate
outline of the general story, scientists’ understanding of the precise mechanisms which underlay the origins of complexity and adaptability in nature is incomplete. Those mechanisms, if they can be better elucidated, are of interest to technologists, particularly in the software arena where simulations can often be written to match a well-defined model. Nature has revealed solutions to some of the hardest problems we can imagine in the design of biological organisms. Correspondingly, one definition of artificial intelligence might be the science of solving hard problems automatically. Discussed in section 5, in recent decades AI has achieved notable successes in its attempts to imitate adaptation in natural systems. The limits of such simulacra of nature are still very real, however, and arguably serve as a proxy for measuring the paucity of our understanding of the adaptive mechanisms in the natural world (as well as, perhaps, the intractability of mimicking it on the computer).

A full treatment of the cases for and against evolution and Intelligent Design is, not surprisingly, beyond the scope of this paper. The aim here is to provide a platform for dialogue, and to begin exploring just one recess in the web of evidence, namely the notion of emergent complexity.

2. Evolution, Local Optima, and Intelligent Design

We begin by visualizing evolution as a search process, so we can quickly see how it is limited. Natural selection works by exploring a “fitness landscape” through mutations and sexual reproduction, looking for peaks that represent survival optima in the current environment. In this way evolution can be seen as analogous to an explorer groping about a mountain range under the cover of darkness, equipped only with an altimeter, and attempting to find the highest peak. The process works best when there is a smooth gradient leading upwards to a maximum, providing small steps that are achievable with probabilistically feasible mutations (see Figure 1). This corresponds to the gradualistic conception of evolutionary progress as a continuous, step-by-step march toward higher fitness and, under the right circumstances, greater complexity. Each correct mutation, i.e. one that results in a large enough birth-rate differential to overcome other population genetic forces, takes part of the population a step up the hill, and eventually replaces lower fitness variants. All “nature’s algorithm” (Cf. [14]) need do is stumble into the so-called basin of attraction of one of these peaks, and then it is straightforward to slide up toward the maximum. This imagery casts the evolutionary process as a stochastic (random) optimization algorithm – although we acknowledge that the dynamics of biological evolution in real-world ecosystems are somewhat subtle, and the analogy should not be taken as gospel.

![Fitness landscape](image)

Figure 1: A fitness peak with a wide basin of attraction conducive to discovery via natural selection.

Constructing good solutions to complex problems is more difficult than the smooth peak with a wide basin of attraction shown in Figure 1 would make it appear, which is why reuse of (previously evolved) information for a new purpose (a.k.a. cooption or exaptation, [22]) has always played a central role in Darwinian theory, and purely gradualistic models of evolutionary history have long been abandoned in favor of such ideas as punctuated equilibrium, in which change occurs in occasional spurts.

In practice all optimization algorithms suffer from the “local maximum” problem, as the fitness landscape is often tumultuous (See Figure 2, taken from a computational model in [52]) The program happily climbs to the top of an easy-to-find, shallow peak, while altogether missing a much better solution with
Figure 2: A more realistic fitness landscape.

a narrow basin of attraction. There is no foreseen benefit to going towards the higher peak, since things don’t get gradually better as we build that system (See Figure 3), and furthermore the valley between them may be too low for the organism to survive at all in an intermediate state.

Since a real fitness landscape has many more than two dimensions, hitting the jackpot by going from one maximum to a distant, distinct maximum is extremely unlikely. Thus severe constraints are introduced into the evolutionary mechanism: most beneficial adaptations are impossible – only a limited subset is capable of occurring. This is readily ceded by evolutionary biology, and has gained emphasis in the past few decades (cf. [21]). What we see is believed to be a highly constrained manifestation of what is possible. Intelligent Design seeks violations of these constraints, i.e. instances where the local maximum problem appears to have been transcended in a manner inexplicable under the traditional neo-Darwinian synthesis of evolutionary theory. That is, it emphasizes the emergence of highly complex systems for which intermediate “stepping stones” are difficult to identify.

2.1. Complexity and Design Inference

The concept of complexity is at the heart of ID, which ultimately asks how much complexity is reasonable to expect of evolutionary leaps given the current state of the theory. A brief application of the Socratic method should convince the reader that a rigorous or quantitative definition of complexity that fits all circumstances is as difficult to synthesize as one for, say, “courage.” As such, scientists use a variety of metrics depending on the problem at hand ([36]).

In [11], Intelligent Design proponent William Dembski provides a general definition of what he calls Complex Specified Information (CSI), which doubles as a proposed criterion for detecting systems which may have been designed. CSI embodies the following properties:

- **Contingency** requires that the system could have been built differently. It is like choosing Scrabble letters at random from a bag. If the bag contains only one type of letter, then our re-

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1Cf. Plato’s *Laches.*
result is not contingent on anything, and we have no grounds to be surprised. However, if the bag contains a large variety of possibilities we may be able to infer design if a given selection can be shown to be unexplainable probabilistically.

- **Complexity** by Dembski’s definition requires that the system have many interdependent parts, without any of which the system would be incomplete and useless.\(^2\)

- **Specification** requires that said system be well suited for the problem we are attempting to solve. Out of the vast array of contingent possibilities, there are many “wrong” answers. In the Scrabble letters analogy, specification could be equivalent to drawing letters at random and trying to form a word in some particular language.

In the context of biology, a system may provide survival value (specification), but with sufficient complexity it can be seen as impossible to have been produced via natural selection. This is because a unit of Complex Specified Information, by definition, cannot be built via incremental steps that each have functional value. Evolution must produce all the information in one large set of simultaneous mutations – i.e. by pure chance. Dembski very generously sets the threshold information content of such an “irreducibly complex” system (to use the term coined by Michael Behe) at 500 bits of information, a number well large enough that it cannot ever be reasonably attributed to chance mutation. If known evolutionary processes are shown insufficient, it is reasoned, then materialist explanations have failed us, and we can infer the presence of design.

At this juncture, the question is often raised of whether it is appropriate to infer design by an agent about which we know nothing, since *design* is understood only in analogy to our much more tangible observations of human (and animal) designs. Extrapolating design inferences to superhuman agents is arguably a questionable application of scientific induction. This is a salient objection, but lies beyond the scope of this essay. In any event, if a system unexplainable by incremental evolutionary processes and requiring 500 bits of information to develop simultaneously and by chance can be firmly shown to exist, it would form a compelling argument at least against evolution if not also for design – though, as we shall discuss, showing with any degree of confidence that there could be no functional intermediate steps and that known evolutionary mechanisms are actually insufficient is easier said than done.

Since the introduction of Complex Specified Information, a great deal of confusion has ensued over what its precise mathematical definition looks like, how it can be experimentally studied, and how it relates to the canonical body of literature on information theory and algorithmic complexity. Many times, scientists have pointed to simple computer simulations that are purported to disprove some of Dembski’s stronger claims, to which ID proponents respond that the supposedly evolved information was indirectly provided by the programmer of the simulation. Often this latter claim is met with bemusement by said programmer (Cf. [15] and [56] for a pro-evolutionary perspective on these simulations, and [16] and [40] for anti-evolutionary analysis).

Clear and polite communication is a major problem in the Intelligent Design debate, and always has been for creationism at large. Before returning to the discussion of biological complexity, then, we need to establish some epistemological context.

3. Hermeneutic Cycles and Misunderstandings

The Intelligent Design movement is a modern extension of the age-old creation-evolution debate, and brings with it the highly charged and polarized rhetorical baggage that has always gone with the domain. Some recent examples from the ID camp:

\(^2\)Note that this definition of complexity implies not only *irreducibility*, but also *brittleness* of the system. Scientists often speak of *robustness* to change/damage as a property of complex systems, however. The two concepts are not incommensurate (For example, the human brain is highly robust to damage, but the genetic sequence that gives rise is most likely brittle in comparison), but clearly care must be taken to describe precisely what we mean by “complex” in a given context.
“Darwinism doesn’t even deserve to be called a theory – it’s a pile of promissory notes for future theories, none of which has been redeemed since the publication of Darwin’s Origin of Species almost 150 years ago.” [10]

“Darwinists [and theistic evolutionists] manipulate the evidence and mix it with theology to recycle a false theory that should have been discarded long ago.” [61]

Scientists have hardly held to a higher standard in their responses:

“Evolution is a fact, as securely established as any in science, and he who denies it betrays woeful ignorance and lack of education, which likely extends to other fields as well... You cannot be ignorant of evolution and be a cultivated and adequate citizen of today.” [8]

“Apparently, everyone in the ID movement just mindlessly copies everyone else’s talking points. None of these folks have a friggin clue what they are blathering about when it comes to flagellum evolution.” [37]

This is the way some of the most well known professionals depict their opponents in modern media, and has been par for the course for nearly a century. When laymen debate the matter, the vitriol can be several times worse. In keeping with the distinction drawn by the ancient Greeks between rhetoric and dialectic, the dominant methods are meant to sway public opinion rather than to converge on truth. As Del Ratzsch points out in his excellent exposé of how both sides of the creation-evolution debate frequently talk past each other ([48]), this long-lived public debate has developed into a social institution in its own right, and “in such disputes the harder the lines are drawn, the less actual communication there is and, indeed, the less importance actual communication seems to have.”

3.1. Christ-Like Dialogue and the Holism of World Views

As in all human disputes, from domestic arguments to war, it is invariably easier to tear down the Other – thus aggravating the dispute – than to work constructively and diplomatically toward truth and reconciliation. With theologian Miroslav Volf, we can take note that while confident, harsh criticism is “not always wrong, it is always dangerous,” since, as often as not, it bears false witness to the Other and blinds us to our own mistakes ([60, p. 57]). The sympathetic dialectic of “double vision” should be preferred, especially for those motivated by the Christian gospel ([59]), but also for those driven by a humble scientific skepticism. The saber-rattling adversarial spirit – which many Christians justify with a (not always fanciful) narrative of persecution from nonbelievers – is largely to blame for the negative perceptions which haunt Christianity (This is neatly documented in David Kinnaman’s popular book, UnChristian [32]).

In looking toward a more constructive, Christ-like method of engaging the matter, then, it is important to observe that interpretation of data, like interpretation of scripture, is a holistic process which sometimes involves an intricate hermeneutic cycle (or, if you like, a paradigm a la Thomas Kuhn, [34]). That is to say, the interpretation of evidence depends on more than the sum of its parts: to take on an opponent’s interpretation of one piece of the puzzle is to take on the whole of his paradigm.

Furthermore, a single piece of evidence that won’t quite fit one’s favorite model is not necessarily enough to falsify it. As biologist Kevin Padian pointed out during the 2005 Dover trial ([33]), a body of theory is “something that is very difficult to slay with an ugly fact, as Huxley once put it... Gravitation is a theory that’s unlikely to be falsified even if we saw something fall up. It would make us wonder, but we’d try to figure out what was going on there rather than just immediately dismiss gravitation.” This mirrors earlier observations by the likes of David Hume, who wrote that “many secret powers lurk” in natural systems, “and that therefore the irregular events, which out-wardly discover themselves, can be no proof that the laws of nature are not observed with the greatest regularity in its internal operations and government.”
The same kind of robustness applies to theological beliefs. Often we find ourselves consternated that when we offer an apparently clear disproof of a theory, the opposition dismisses it as an “ugly fact” or a curiosity that poses little serious challenge. The opponent may go on to propose apparently wild modifications to their theory to make it fit the new data. This rejiggering, if handled carefully, is a valid part of the scientific method, but lends itself to misunderstanding when the justifying framework is not shared between interlocutors. Thus Kuhn argues that the logic of an opposing paradigm “cannot be made logically or even probabilistically compelling for those who refuse to step into the circle” ([34, p. 94]).

When communicating across paradigms, it is important to keep the whole picture in mind if one expects to make compelling criticisms. We must “inhabit imaginatively the world of others,” and “view events in question from the perspective of others, not just [one’s] own” ([60, p. 57]). That means laying aside the provocative demands of bellicose activists, perhaps even leaving them unrefuted (depending on whether you prefer verse 4 or 5 of Proverbs 26), and instead engaging in a respectful and non-patronizing dialogue – that is, a two-way discussion with give and take – about how exactly evidence is synthesized to form the foundation of each other’s hermeneutic cycles. Letting the Other portray their paradigm in their own language helps mitigate the tendency to force them into a straw-man sized box.

### 3.2. Example: A Hermeneutic Cycle for Design

In an attempt to demonstrate these principles, consider the “puzzle piece” that arguably has the largest impact on an individual’s readiness to accept design: belief in the Judeo-Christian or Islamic God. A cartoon depiction of the associated hermeneutic cycle is shown in Figure 4, inspired by graphical models, or more specifically *Bayesian belief networks* ([44]), which are used in computer science for representing complex joint probability distributions.

When encountering a system that appears irreducibly complex, *a person who already believes in a creator God will be much more ready to accept that God is behind the complexity, and that evolution is an insufficient explanation*. Since she already believes in a competing mechanism, she will demand more evidence before accepting an evolutionary explanation. She may even be willing to modify her picture of how, exactly, God chose to create, in order to fit unexpected patterns in the empirical data (within the constraints set by her understanding of scripture, of course). To effectively challenge her conclusions, an interlocutor would need to engage her belief in the creator, not just the science. This may be difficult for the interlocutor to understand, especially if his hermeneutic cycle lacks a preexisting belief in a designer. His objections may take on an air of capriciousness as he demands highly specific evidence of a designer that would create in a manner so conveniently consistent with the predictions of evolution.

### 3.3. Example: A Hermeneutic Cycle for Evolution

On the flip side, Intelligent Design sympathizers often fail to understand that the foundation of an evolutionist’s belief – since Darwin – has little to do with the proven ability of mutation to effect complexity, and *everything* to do with how well the paleontological, biogeographical, anatomical, genetic, and molecular data fits the predictions of a natural process of common descent with modification (Figure 5). Evolution does not purport to know with perfect precision how this took place, and there are significant open questions regarding the limits of adaptationist “just so” stories ([21]), convergent evolution ([41]), and cooption ([58]). Within the constraints of the enigma, then, scientists readily calibrate their understanding of the limits and dynamics of these mechanisms, rather than rejecting them, when they encounter surprising data. This recalibration is a legitimate scientific strategy (when used carefully) that...
Personal Experience

Scripture

Creator Exists

Data Consistent with Common Descent

Complex System X was designed

Modified Creation Theory

opponents tend to ungraciously misconstrue as “moving goalposts,” “fact-free science,” or “circular reasoning.”

Since our knowledge of the power and limits of evolution is incomplete, critics have been unable to demonstrate conclusively that any observed system violates the theory’s capabilities – certainly not to the point that merits rejection of common descent on those grounds alone. These critics are quick to point out, shifting the burden of proof, that neither have evolutionists demonstrated conclusively that observed systems do not violate these limits, and that some sort of design could well be considered to have occurred in tandem with natural mechanisms (thus being consistent with the evidence for common descent). Nonetheless, the overwhelming majority of biological researchers remain perfectly comfortable accepting evolution sans intelligent interference as the most parsimonious reading of the data, at least until ID-style arguments, which in their current state are redolent of a “God of the gaps,” become an order of magnitude stronger.

3.4. Constructive Criticism Takes Effort and Respect

There is certainly variety in the world views of both camps, and these cartoons should not be taken as canon. Regardless, the implications of these sketches are that one’s opponents may, on closer analysis, not be as thick-skulled or stubborn as they seem. Even if they are still ultimately wrong, the task of showing how they are wrong is complex, and cannot usually be accomplished with pithy rejoinders or by shifting makes that can be verified without modifying the model. In statistical learning theory, this is related to the idea of splitting data into training and validation sets. Unfortunately the process is more delicate when the learner is a human and not a computer, and often forms a point of confusion in debates over the merits of a theory.

Responding to the efforts of scientists (specifically in [6] and [43]) to provide plausible accounts of the origins of the bacterial flagellar motor, for instance, Dembski writes “So what? We can imagine lots of things. Where’s the evidence that it happened that way? And why isn’t the exquisite engineering that we observe in the flagellum evidence for ID?” On such matters, Dembski frequently accuses his opponents of “bluffing” ([13]).
System X appears irreducible complex

The burden of proof. Furthermore, even philosophers seldom walk around with diagrams of their paradigms in their heads, ready to pull out to assist communicating with the Other. They must be constructed through time-consuming reflection and dialogue. It can take a long time to explain to one’s self, much less others, the full justification for a particular belief.

The result of such dialogue will (in theory) be that one develops a more comprehensive and sympathetic understanding of the alternative interpretation, while at the same time the key assumptions that are not shared between the parties will become evident. Only once the gestalt of plausible belief is better understood is one prepared to send opposite arguments across the channel of communication, perhaps convincing the Other that there is more value in the opposing interpretation than he at first supposed.

This kind of honest clarity is, of course, easier to idealize than to achieve. Activism and evangelism, in their efforts to win ideological battles, avoid it routinely, almost by definition – ergo the stereotype suffered (and not altogether unmerited) by politicians, clergy, and the New Atheists as having two mouths and one ear.

The reason Intelligent Design is so controversial is that it purports to offer a complete, stand-alone case strong enough to establish design and disprove the complete hegemony of Darwinism without referring to scripture, personal faith or other religious motivations – i.e. a case that should be compelling enough to be included within science as, at the very least, a respectable alternative to raw evolution, thereby putting the prestige and influence of science behind an idea formerly confined to matters of faith. It is when scientists resist these claims that fireworks ensue on both sides.

With awareness of the complexities of hermeneutic cycles under our belt, we are now prepared to delve into the fray systematically by engaging a few, specific hermeneutic nodes – setting aside at present the more charged question of whose paradigm is ultimately correct.

3.5. Methodological Naturalism

First, a word on the red herring of methodological naturalism. This philosophy takes the stance that
science cannot deal with the supernatural since, as
a method of seeking the truth, science by definition
deals with the natural world exclusively. This is sup-
ported by many scientists, believers and nonbelievers
alike, who feel that opening the door to the divine
stifles inquiry by prematurely replacing the not-yet-
understood with “God did it” ([9, pp. 132–134][51]).
Molecular evolution pioneer Richard Lewontin, for
instance, has stated that “We cannot live simultane-
ously in a world of natural causation and of miracles,
for if one miracle can occur, there is no limit” ([35]).

Methodological naturalism is often used as a short-
cut to eliminating Intelligent Design from scientific
discussions a priori – a view famously given impetus
by Judge John E. Jones III in the 2005 Kitzmiller
vs. Dover Area School District ruling, which de-
clared that Intelligent Design is not science ([26]).
This comports with the cornerstone of the rhetorical
case Dembski and others make for ID, which asserts
that the primary reason science has refused to ac-
cept the arguments for design is not a scientific one,
but instead based in a philosophical presupposition.
This rebuttal, however, amounts to a shortcut that
discredits the opponents of ID a priori.

Not all scientists support a parsimonious method-
ological naturalism ([54, p. 35]), and so in the interest
of not prematurely terminating the discussion, here
we will not assume that it is a prerequisite for sci-
entific inquiry. Instead we will hold that hypotheses
involving divine intervention, while perhaps difficult
to substantiate, can in principle be applied responsi-
bly and scientifically. For justification, we offer only
the following thought experiment: If solid evidence
were at hand that extraterrestrials built the pyra-
mids, scientists would have no qualms accepting it
and trying to learn more about the aliens, regardless
of how mysterious and powerful they might be. God
can be treated similarly. For more discussion on defi-
nitions of science with regard to design and evolution,
see [48].

Regardless of one’s stance on the possibility of in-
ferring the divine scientifically, it is readily accepted
that “if genuinely irreducible complexity could be
properly demonstrated, it would wreck Darwin’s the-
ory” ([9, p. 125]). We thus consider the hypothesis
“natural evolution is insufficient to explain apparent
irreducible complexity” to be a valid (and scientific)
point of inquiry, and want to set out to inform our
opinion on the matter with evidence.

3.6. A Model for Evaluating ID

What we have at hand are two (rather grandiose)
competing hypotheses regarding how complex pro-
cesses in life came to be which make the following
broad statements and predictions, each of which are
themselves hypotheses to be tested. We now pro-
ceed to break the matter down to an almost pedantic
level, in an attempt to provide a common interpretive
framework.

1. Supernatural:
   • A) Complexity exists that is difficult to ex-
     plain with natural causes.
   • B) Complexity exists that has no natural
     explanation.
   • C) Some sort of supernatural entity de-
     signed this complexity.

2. Natural:
   • A) Simple in vitro and/or in silica6 pro-
     cesses can produce a profound amount of
     superficial complexity.
   • B) Similar in vivo natural processes do pro-
     duce some of the complexity we see in na-
     ture.
   • C) Similar natural processes produce all
     the complexity we see in nature.

Note that 1.B, the lynchpin of the ID debate, has,
in the terms of first-order logic, two existential quan-
tifiers: There exists (\exists) complexity for which there
does not exist (\neg \exists) a natural explanation. Between
the two of them, these quantifiers remove hope of
proving the matter one way or the other, in the math-
ematical sense of absolute logical proof, but we can
still decide which is most likely.

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6 In silica refers to an experiment conducted solely via com-
puter simulation.
Figure 6: Bayesian relationships between the hypotheses.

First, the hypothesis that a given system has no natural explanation (1.B), being a negative existential (¬∃), is very difficult to prove. Its verification depends on an assurance that we know the limits of all natural processes and that we can identify violations of those limits (which, as we have already mentioned, is easier said than done). We cannot be completely certain we have ruled out all natural explanations – but if we consistently fail to explain apparently complex systems with natural law (1.A), we may legitimately believe that 1.B is very probable.

Second, disproving 1.B is equivalent to proving the hypothesis that natural processes produce all complexity (2.C), which is 1.B’s negation. The negation makes the first existential a negative (There does not exist (¬∃) a complex system with no natural explanation). Since we cannot enumerate all systems that exist in the universe and verify that they originated naturally, we cannot prove 2.C, and therefore cannot disprove 1.B. Again, however, our confidence in it is reduced as we succeed in explaining more and more of how systems which appear highly complex could be (2.A) and (especially) are explained by natural process (2.B).

Figure 6 summarizes the inferential relationships in one of our cartoon hermeneutic cycles. Single lines represent supporting (black →) or detracting (red →) evidence, thicker lines having more effect than thin ones. Double lines (⇒) represent logical proof/disproof.

The idea is that, as we steadily unveil more of the available evidence, we add or subtract from our confidence regarding Intelligent Design. Our evidence comes in two forms: apparent irreducible complexity on the one hand, and the potential to explain it away on the other as computational and physical experiments threaten to unveil simple explanations for an arbitrary level of apparent complexity.

4. Apparent vs. Real Complexity

Notice the introduction of the term “apparent complexity” in the previous section. This is our central insight: In seeking examples of irreducible complexity, our efforts are confounded by the difficulty of inferring the existence of “genuine” complexity to begin with, at least in certain classes of systems. There are at least two distinct forms this sleight-of-system can take in the context of evolution:

1. A system (or modification to a system) that appears irreducible, and does require a great deal of information to specify, is not actually irreducible: useful intermediate steps exist by which it can be built without any information-intensive leaps.

2. A system (or modification to a system) that is irreducible, and appears to be information-intensive, does not actually require a great deal of information to specify.

The first is the established domain of most debate over irreducible complexity. This mode of explanation speculates about the history of the system in question, and argues that similar systems existing in the species’ ancestors for different roles could act as stepping stones to make the development of the present system easier. Feathers, for instance, are proposed to have originated as thermal insulation for theropods ([45]). Similarly, it is pointed out that almost all (rather than a small subset, as commonly

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This is the Bayesian formulation of inference from evidence, and is a mathematized pillar of probability theory. Of course, we can only use it qualitatively to represent human reasoning.
believed) of the proteins that are vital to the function of the bacterial flagellar motor (the traditional poster-child for irreducible complexity) have homologues, i.e. similar proteins, that are put to other uses in bacteria ([43]). This concept of reuse, or cooption of information is integral to evolutionary theory, and has been discussed at length elsewhere ([27][58]). It forms an extremely important node in the evolutionist’s interpretive framework.

Our focus in the below will be on the second possibility, in which a seemingly complex system actually has a low information content – i.e. on closer analysis we would be inclined to say it is not actually complex. Complexity researcher Yaneer Bar-Yam underscores this issue in the context of constructing models of biological systems:

“Complex phenomena require, by their nature, a complex model to generate them. This means we cannot expect simple models to generate truly complex behavior. Thus, a basic skepticism about the ability of theory to describe biological phenomena can be justified. What is missing, however, is an ability to know, a priori, what are truly complex phenomena and what properties of complex organisms can be attributed to simple universal behaviors.”[4, p. 690]

Here we find that simple physical and mathematical experiments can shed light on the question of how much information is actually required to determine a system that would appear complex to the observer. This approach is common in science, wherein “simple models with a minimum number of parameters,” writes one researcher, “allow for the determination of the basic ingredients necessary for the emergence of complex structures” ([46]).

While examining simulations of complexity in various fields may not tell us something for certain about natural systems, it does affect our picture of how apparent complexity may or may not arise from simple origins in a variety of situations, and thus the paradigm from within which we evaluate Dembski’s work.

4.1. Kolmogorov Complexity

We will loosely apply the term intricacy to denote systems that strike us on the surface as being complex, and consider it to correspond to an observer’s naive intuition of “hard to evolve.”

Dembski’s definition of Complex Specified Information implicitly deals with the question of the minimum information actually required to specify the system (genotype), as opposed the high-level intricacy we observe (phenotype). One well-established metric intimately connected to this concept is Kolmogorov or algorithmic complexity, which is closely related to Shannon’s information theory. Like CSI, Kolmogorov complexity rests on the notion of how probable a particular string of information is given a random distribution (such as mutation) that generates it ([7]).

Any string of information that displays regularity or a pattern can be compressed, described by an algorithm that can be expressed in a relatively small amount of data. For example, to transmit the string “ABABABABABABAB” we needn’t transmit each character individually, but can instead send “7*(AB)”, meaning “AB” is repeated seven times. Or if we want to convey the base-1 message “1111111111111111111” it can be compressed to “10011” in base-2. Another example can be found in numbers: The integers $2^{100}$ and $(100)!$ are easy to specify in just a few symbols given our notation system, even though we can prove that most large numbers cannot be expressed so easily, i.e. they are more complex. Kolmogorov complexity is defined to be the shortest possible signal (or string of symbols) and decryption algorithm pair that can be used to reconstruct the original signal within the given computational environment (be it chemical or digital).

Using this metric, the most complex string is a purely random one. Randomness cannot be compressed, since it displays no regularity. But randomness is minimally informative (i.e. not very useful), so Dembski has clearly stated that Complex Specified Information is correlated with low Kolmogorov complexity ([12]). This at first appears contradictory, since too few bits of complexity, if they correspond directly to a genetic sequence, can be discovered by chance, and thus no longer meet the criteria
for irreducible complexity. Thus complexity metrics have been proposed which rank large, non-random strings as complex and large, random (and thus useless) strings as not complex, more in line with what we’d expect, but they take special effort to apply ([18][47, p. 80]).

In any event, Intelligent Design’s core argument still rests on the assumption that irreducibly complex systems exist which have high Kolmogorov Complexity, not to the point of being random, but to the point of being undiscoverable by simple mutations.

4.2. Emergent Complexity

The examples we saw in the previous section of compression of patterns into a few symbols were somewhat mundane. But it turns out that, under the right circumstances, surprisingly intricate patterns can arise from a very small amount of compressed information – a phenomena we will loosely refer to as emergent complexity. This was not discovered until the advent of digital computers, which allowed us to study at length the properties of nonlinear dynamical systems and algorithms for the first time (Cf. [20] for a telling of this story).

A simplistic example is found in the icosahedral shells of viruses, which demonstrate how nature can exploit the laws of mathematics to create an intricate, ordered structure from a small amount of compressed information (See Figure 7). Here, striking icosahedral structure self-assembles out of many copies of a single protein ([2][63]).

These structures are visually appealing and apparently irreducible in the sense that removing a face of the icosahedron would destroy its functionality. But a small amount of genetic information is required to produce it. As with many other highly symmetric self-assembling molecular structures like microtubules and actin filaments, however, this is not terribly surprising to our eye: icosahedral structures can be rotated 60 different ways and still look exactly the same to the observer. It is clear that they have low Kolmogorov complexity.

More jarring to our intuition is the discovery that brief algorithms can be defined which, by repeating the same operation, self-organize or emerge into astounding structures which the viewer would assume have much more complex specifications. A classic example is the fractal pattern evident in the Mandelbrot set.

The idea of a “fractal” is somewhat ill-defined, but at its heart lies the concept of self-similarity – a property shared by many nonlinear and chaotic systems – in which a subsection of the system contains a scaled-down snapshot of the whole. Like the symmetry of the icosahedron, this betrays the underlying regularity of the system – and yet it is so intricate that it seems improper to say a fractal is not “complex.” This is readily apparent in the famous Mandelbrot
set, in which the scale models are accompanied by beautiful swirls that look like the brush strokes of a talented artist. And yet no human being specified this painting: the entire system is described by the straightforward complex (as in imaginary numbers) polynomial:

\[ z_{n+1} = z_n^2 + c \]

which is arguably the simplest conceivable nonlinear map in the complex plane.\(^9\)

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\(^9\)The renderings of a 3D version of the Mandelbrot set in figure 9 were created by Daniel White, used with permission. Learn more about the model at http://www.skytopia.com/project/fractal/mandelbulb.html

Another visually appealing example of emergence in physics is found in the so-called “nanoflowers” that have been synthesized in laboratories under a variety of conditions (Figure 10). The structures apparent in Figure 10 were created by heating gallium nitride on a silicon substrate to 1100°C and then exposing the system to methane gas. “Interest in such structures,” writes the Cambridge research team who developed the experiment, “centres around the combination of a simple growth process based on SiC nanowire formation, with a resultant structure having potentially complex mechanical and optical properties” ([23]).

Dembski is fully aware of emergent complexity (or, in our vernacular, emergent *intricacy*) in systems such as these, as well as the hype surrounding them. At this juncture he makes an important observation regarding the Mandelbrot set: it takes more than this simple equation to produce the famous picture.

“Any function that produces a graphic

...
depiction of the Mandelbrot set will be a complicated algorithm employing a complicated set of input data... But by itself the function $h(z) = z^2 + c$ is too information-poor to produce this graphic depiction of the Mandelbrot set $j$. Once we examine the precise informational antecedents to $j$, the illusion that we have generated information for nothing disappears" ([11, p. 165]).

In our initial examples of Kolmogorov complexity, we didn’t discuss how much information is required to specify the algorithms that decompress “7*(AB)” or convert base-2 back into base-1. Like any computer graphics program, displaying the Mandelbrot set takes a good deal of code. Kolmogorov Complexity depends on the computing environment. Just like it is easier to write the code for a desktop application in a high-level computer language than in machine-level byte code (1’s and 0’s), systems like the Mandelbrot set require an underlying framework to operate in.

The structure of the Mandelbrot set is infinite and ever-changing, and its requisite algorithm is by no means large – Dembski describes the details in a single paragraph. And no one designed the swirls and patterns in the image – they were discovered to manifest from an elementary application of the equation $z^2 + c$. Nevertheless, Dembski is correct that the framework for executing such a program must be in place before a nonlinear formula can work its magic.

4.3. Emergence in Biology

The significance of the role played by self-assembly and emergence in determining phenotype from genotype is a matter of debate within the biological community. The notion that it is highly significant is elegant and attractive: under this view evolution remains highly constrained on the genotypic level, but our picture of what it is capable of changes on the phenotypic level. In searching for Hume’s “many secret powers” which “lurk” in the recesses of our understanding, one could hardly find a more titillating candidate for natural creativity than emergence coupled with cooption. More evidence is required, however, to upgrade an idea from “elegant” to “demonstrated.”

We have seen in icosahedral viruses, the Mandelbrot set, and nanoflowers that – given the right conditions – a simple underlying process can generate a startling level of high-level intricacy. However, the structure of the viruses was still rather simple, and there is certainly no reason to believe that biochemistry implements the complex number system (in which the Mandelbrot set lives), or that it facilitates the growth of anything like nanoflowers.

Before emergence can have any reasonable significance to the debate over irreducible complexity, we must make the argument that the framework (the “computer” that decodes our compressed string of information) in real-world organisms allows for advanced, intricacy-generating processes. Furthermore, we must have some reason to believe the structures thus developed have a reasonable shot at being useful, i.e. achieving Dembski’s specification criterion.

10 The algorithm for 3D versions of the Mandelbrot are more complicated. But the 2D rendition is considered the “true” Mandelbrot set.
Even if emergence is highly apposite to evolutionary biology, the case is a difficult one to make in a clean way experimentally. Even if the initial development of a system involved only a few parts, evolution is free to tinker and add bells and whistles to its heart’s content. We would not expect to find parsimoniously low-Kolmogorov-complexity systems in biology, and thus do not expect to find an example as striking as the Mandelbrot set.

We can still ask the question, however, of whether biology provides a suitable framework for emergent complexity to occur. We know that emergent complexity requires processes that are nonlinear – that is, which include a feedback mechanism. Biology, it turns out is replete with nonlinearity. Protein folding and self-assembly of molecular structures displays nonlinearity, but perhaps not the sort of ongoing process required by the Mandelbrot set and nanoflowers to generate highly intricate superstructures. Thus it seems reasonable to assert that emergence does not play a major role in, for instance, developing the bacterial flagellar motor.

Where emergent complexity is more likely to be amenable to utilization by evolution is in developmental processes. The conversion of genotype to phenotype – that is, ontogeny – is quite subtle, and makes heavy use of feedback mechanisms encoded in genetic regulatory networks: genes which are switched on and off (or somewhere in between) by proteins, which in turn are produced by other genes, which may be affected by other proteins, etc. These dynamics ultimately lead to a subtle interplay between intercellular signaling and cell differentiation (the transformation of a cell from one type into another), thus defining the structure of the organism as it develops.

Kauffman showed in [29] and [31] that simple genetic networks can display surprisingly intricate dynamic behavior. The in silico study of Lindenmayer systems and other generative encodings – simple, abstract models meant to mimic ontogenic processes – has provided compelling models for plant-like branching structures ([17]). These models fuel the intuition that it doesn’t take all that much information to alter a developmental process and thereby produce significant changes in phenotype.

Even if the reader is not convinced that anything so magical as the Mandelbrot set is at evolution’s disposal for achieving useful ends, the dynamic “unpacking” of genetic information into a higher-level structure should incite caution with regard to claims that macroscopic features of an organism are irreducibly complex. Looking at the proposed steps toward the evolution of the eye, for instance, and calling “too complex” presupposes that our intuition regarding how complex each step is accurately reflects the amount of genetic chance required to modulate the underlying genetic regulatory networks in such a way that change is produced. We have no such assurance.

In biology, small changes can have large effects that generate regular macroscopic features, and a subset of these effects may be useful to the organism ([19],[27]). Biologists consider it unlikely that large phenotypic leaps (a.k.a. “macromutations”) play a major role in evolution, but in light of regulatory networks and developmental processes they still tend to impart more power to small mutations than is appreciated by those who find traditional creationist arguments like the complexity of the eye compelling. Part of this understanding stems from emergence, where it is understood that a small modification in the regulatory process that generates a phenotype (or the chemical process that generates a nanoflower) has significant and not-always-destructive high-level effects on the resulting structure.

In light of these observations, Darwin’s point from the famous sixth chapter of the Origin of Species maintains currency:

"...we should be extremely cautious in concluding that an organ could not have been formed by transitional grades of some kind."

4.4. Recommended Reading

There is a host of accessible literature written about complexity and its sister fields by scientists of great renown. For those interested in learning more about the matter at an introductory level, [20], [24], [29], [38], [39], [53], [55], and [62] are some of the better-known books which may prove useful.
5. Adaptive Computing

A significant portion of modern Artificial Intelligence research seeks to imitate the emergent behavior of biological systems. We can think of these applications as a sort of laboratory to test our understanding of the natural mechanisms that might give rise to specified complexity. If we genuinely understand how biological solutions arise, then we should be able to emulate those processes to solve our problems. Indeed these attempts have allowed us to solve profoundly difficult problems and develop practical solutions that are otherwise intractable.

For instance, broad classes of difficult optimization problems can be solved by algorithms that take inspiration from nature. One method takes direct inspiration from evolution, as we have seen. Other powerful methods imitate the way ants forage to find food, and share information via pheromone trails about which search routes are promising. This approach, along with other methods such as particle swarm optimization, take advantage of how the behavior of individual agents – each of which are quite stupid in isolation – leads to intelligent problem-solving when taken en masse. Artificial neural networks constrain this parallel problem-solving strategy slightly closer to human intelligence by imitating adaptation in neural circuits. Instead of programming the computer directly, the engineer of a neural network defines the general neural architecture, and after that the system uses various adaptation rules (many of which are derived from the neurobiology literature) to produce a network capable of solving the problem at hand.

The solutions produced by such systems are often too complex to reverse engineer, and remain a black box to their creators – and so to characterize them as solely the products of human design would be somewhat disingenuous. While only a small subset of adaptive algorithms are inspired by evolution (or even biology – many, such as the popular Support Vector Machine, are strictly mathematical in origin), all seek to define systems which learn automatically from their experiences and are capable of developing non-obvious solutions with little to no input from a designer, and thus are to some extent analogous to evolution.

Despite the success of these techniques in generating solutions their creators never imagined, artificial neural networks are far, far off from the power of a biological brain, and artificial immune systems (which have inspired another class of computer algorithms) do not display the sort of powerful adaptability evident in their human counterpart. The evolutionary approach \textit{in silico} is not a magic formula that can relieve the engineer from his responsibilities as designer, as Bar-Yam points out:

\begin{quote}
\textit{While the GA/EA \textit{[genetic/evolutionary algorithms]} approach can help in specific cases, it is well known that evolution from scratch is slow. Thus it is helpful to take advantage of the capability of human beings to contribute to the design of systems.}\textsuperscript{[5]}
\end{quote}

A major impediment to developing complexity \textit{in silico}, as noted by Thomas Ray (\cite{49}), Luis Rocha (\cite{50}) and others, is the difficulty in implementing the immensity of biological mechanisms and ecosystems: respectively the groundwork for emergence and the “unplanned openness of nature in which natural selection can turn to its advantage whatever chance offers” (\cite[p. 217]{28}). Real-world evolution operates in heterogeneous and changing environments which facilitate the all-important \textit{cooption} (\cite{19}\cite{27}\cite{42}\cite{57}), which traditional applications of evolutionary computing seldom attempt to imitate. Even if we could deduce how to simulate the elemental features of such a system, it is possible that a tremendous amount of computing power would be required to run a process capable of generating significantly complex artifacts. Perhaps digital simulation of true evolution is outright impossible (as argued in \cite{30}). Wide classes of questions remain open to further research, and some continue to push for “a more sophisticated dialogue between computational and natural scientists about evolution” (\cite{3}).

Given the involved nature of real-world evolution, the models we have for how complexity emerges in nature have not provided us so far, whether for lack of insight or lack of computational power, with the detailed mechanistic understanding required to implement comparable artificial solutions. This signals
us that we have more to learn, and that our models still require a lot of fleshing out before we can pretend that we fully understand the nature of high-level reality.

6. Conclusion

The constraints evolution’s capabilities are bound by are not precisely known. The evolutionist’s hermeneutic cycle – that is, his conviction of common descent – leads him to believe that natural selection and mutation are sufficiently powerful to produce what we see. It would take a very well established case to convince him that the constraints of the theory have been violated. For the majority of scientists, the extant evidence is sufficient to establish evolution on solid ground. The fact that he cannot prove conclusively that irreducible complexity does not exist somewhere in biology, or even that a particular system is not irreducibly complex, is not a great source of concern.

So in a sense, the deck is stacked against proponents Intelligent Design, who fight against a belief in the power of cooption and emergence that they cannot disprove. Science is simply not advanced enough to prove irreducible complexity to the satisfaction of the scientific community. Scientists are not prepared to invoke the miraculous when they observe an irregularity (ex. when something “falls up”), especially not with any degree of confidence, when a plausible natural explanation is readily at hand. Intelligent Design is a radical hypothesis for which there is no independent evidence in science – the only evidence that exists is the evidence it was introduced to explain. Cooption and emergence, by contrast, are understood phenomena for which there is independent evidence in many special cases.

A better route toward falsifying evolution is to find solid examples that violate other predictions of common descent – the real core of evolutionary theory. Again, the constraints that common descent is subject to are not fully understood, so falsifying it would take some work. Irreducible complexity is one example of a potential violation, but is difficult to prove. Similarities found between unrelated species are another such violation, but can often be explained as convergent evolution. Not all such occurrences fit neatly into the convergent evolution paradigm, however, especially on the molecular level. Evolutionists are not surprised to see similar proteins or similar eyes in humans and the octopus, and there is wide disagreement over how frequently we should expect such events – but if the two organisms shared a nearly identical genetic sequence for a large set of proteins, that would be a big surprise to everyone. The discovery of enough such violations would place a severe strain on the theory of common descent that, under the right conditions, could be fatal to the theory.

Intelligent Design also has fuzzy constraints that make it difficult to disprove. Since cooption and emergence usually cannot be shown conclusively to explain a system, design is always an option. For someone who already believes in a designer – for reasons of personal experience with the Holy Spirit or the miraculous, for instance – the possibility of design is always a real one. He may thus be reluctant to accept cooption as an explanation for a given system, even when the scientific community is readily convinced of it. When evolutionists point to evidence for common descent, he will explain that God chose to reuse information in his creation, and that apparently God chose only to reuse information in a tree pattern for eukaryotes – i.e. in a manner easily mistakable for common descent. He thus alters his picture of the constraints God chose to place Himself under, and of which we are mostly ignorant, rather than reject his belief in design – a balancing act that is as legitimate given his hermeneutic cycle as it is for an evolutionist to calibrate his intuition regarding the power of mutation.

In conclusion, Intelligent Design can be a valid part of a religious world view already established via some other evidence, but given our current scientific understanding, *ID cannot be used to prove the existence of a designer*, per se, or even to disprove naturalistic evolution. That said, much work needs to be done before one can take scientists’ confidence that “evolution happened” and transmute it into the statement that we understand “how evolution achieved what it did.”
# References


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