The Fallacies of Intelligent Design Theory

The Information Theory Case Against Evolution

Mathematician William Dembski, an ardent ID advocate, uses information theory to attempt to prove that life and the universe cannot possibly be the result of either natural processes or chance. Neither mechanism, he insists, is capable of increasing information. Thus, there must have been an intelligent designer.

SECULARISM: Exclusion of religion from public affairs - Religion and religious bodies should have no part in political or civic affairs or in running public institutions. Rejection of religion or its exclusion from a philosophical or moral system.

“Ref: Encarta World English Dictionary, 1999”

Dembski is inconsistent in his use of the term “information.” In his words, he implies the common understanding of information as a measure of knowledge (meaningful content) about a system. But in his mathematics, he defines a quantity of information that is identical to what is known as *“Shannon uncertainty”*, which refers to the number of bits needed to transmit a signal communicating a message, irrespective of the content of the message. This is important, because, in information theory terms, Shannon uncertainty has nothing to do with the content of the message transmitted. It has to do with the volume of bits transmitted. If Dembski’s law is meant to be applicable to information theory, as its name implies, it cannot be applied to a text’s meaningful content. He inconsistently switches back and forth between these concepts of information theory.

In information theory terms, the conventional definition of information, consistent with the vernacular use of the term mentioned above, is: the decrease in Shannon uncertainty under the action of some process. Thus, if fewer bits are needed to describe a system after the process, information about the system has been obtained. It is not clear the extent to which Dembski understands this.

More important is Dembski’s “law of conservation of information,” which states that the number of bits of information cannot change in any natural process such as chance or the operation of some physical law, i.e., chance and laws working in tandem cannot generate “complex specified information” (meaningful content). Since the universe contains information, that information must have come about by other means (which he labels intelligent design) (Dembski: 1999). While he insists that this argument does not depend on any specific theological assumptions, his writings promote his interpretation that the design is the work of the Christian god.

To provide a background for understanding Dembski’s argument and how it is mistaken, a short discussion of information theory is presented.

The Science of Information Theory

"Information" as understood in information theory has nothing to do with any inherent meaning in a message. The word is used to mean the degree of order, of non-randomness, that can be measured and treated mathematically much as mass or energy or any other physical quantities are.

The science of "information theory" began during World War II. Information theory is a branch of the mathematical theory of probability and mathematical statistics that studies the communication process, viewed as the transmission of information. Essentially, information is a measure of a system's randomness, which can be identified, sent, and received only if it is recorded in the structure of a material medium (including electromagnetic waves).

Although information is sometimes measured in characters, as when describing the length of an email message, the convention in information theory is to measure information in bits. A "bit" (the term is a contraction of binary bit) is either 0 or 1. Because there are 8 possible configurations of three bits (000, 001, 010, 011, 100, 101, 110, and 111), three bits can be used to encode any integer from 1 to 8. All logarithms are expressed to the base two, so log 8 is 3. Similarly, log 1000 is slightly less than 10 and log 1,000,000 is slightly less than 20.

Suppose a coin is flipped one million times and someone writes down the sequence of results. If you want to communicate this sequence to another person, assuming it is a fair coin, so that the two possible outcomes, heads and tails, occur with equal probability, and each flip requires 1 bit of information to transmit, transmitting the entire sequence of tosses will require one million bits.

Suppose that the coin is biased so that heads occur only 1/4 of the time and tails occur 3/4 of the time. In this case, the entire sequence can be sent in 811,300 bits, on average. This implies that each flip of the coin requires just 0.8113 bits to transmit. But you cannot transmit a coin flip in less than 1 bit, when the only language available is zeros and ones. However, if the goal is to transmit an entire sequence of flips and the distribution is biased in some way, one's knowledge of the distribution can be used to select a more efficient code, as described below. A sequence of biased coin flips contains less "information" than a sequence of unbiased flips, so it should take fewer bits to transmit.

The information content of a sequence is defined as the number of bits required to transmit that sequence using an optimal encoding. Suppose we roll a die with eight faces. Since eight is a power of two, the optimal code for a uniform probability distribution is: log 8 = 3 bits. Information theory provides a formula (see below) for determining the number of bits required in an optimal code even when we do not know the code. Consider uniform probability distributions where the number of possible outcomes is not a power of two. With a fair six-sided die, the number of bits required to transmit one throw is: log 6 = 2.58. Though a single throw cannot be transmitted in less than 3 bits, a sequence of such throws can be transmitted using 2.58 bits on average. One way to transmit less than 3 bits/throw is to consider them three at a time. The number of possible three-throw sequences is $6^3 = 216$. Using 8 bits, we can encode a number between 0 and 255, so a three-throw sequence can be encoded in 8 bits with a little to spare.

In probability terms, each possible value of a six-sided die occurs with equal probability P = 1/6. Information theory tells us that the minimum number of bits required to encode a throw of the die is -log P = 2.58. In the eight-sided die example above, every message had a length exactly equal to -log P bits. For biased (non-uniform) probability distributions, let the variable x range over the values to be encoded and let P(x) denote the probability of that value occurring. The expected number of bits required to encode one value is the weighted average of the number of bits required to encode each possible value, where the weight is the probability of that value:

$$H = \text{avg. bits required} = \sum_{x} P(x)[-\log P(x)].$$

H, which is the number of bits needed to transmit a signal communicating a configuration, irrespective of the content of the message, is known as Shannon uncertainty. A more conventional definition of information that is consistent with the vernacular use of the term is $R = H_{before} - H_{after}$, the decrease in Shannon uncertainty under the action of some process. If $R > 0$, information has been gained, there has been an increase in order, and fewer bits are now needed to describe the system. Shannon uncertainty is a measure of the randomness in a signal that is applied in communication theory.

One of the measures of information is a quantity called entropy, which quantitatively characterizes the level of disorder in a system, i.e., how much randomness is in a signal. An alternative way to look at this is to consider how much information is carried by the signal. The more information carried by a text, the larger the text's entropy. The total entropy of a text as a whole is proportional to the text's length. As an example, consider some text, encoded as a string of letters, spaces, and punctuation (so the signal is a string of characters). Since some characters are not very likely, e.g., z, while others are very common, e.g., e, the string of characters is not really random. On the other hand, since we cannot predict what the next character will be, it does have some randomness. Entropy is a measure of this randomness. Except for units and a different base for logarithms, Shannon uncertainty and entropy are identical. Shannon referred to his quantity H as entropy, just expressed in bits rather than the Joules per Kelvin units of conventional physics.

Consider a string of the same letter (like A) repeated over and over: AAAAAAA...etc. This meaningless text is perfectly ordered, and thus its entropy is essentially zero. Now consider an extremely long text (string) obtained by randomly drawing letters of the alphabet (and a space) from a container, writing down the letter drawn, and returning it to the container. This string will almost always be gibberish. Thus, there is no or very little order in the random string, and the entropy of the meaningless information carried by that string is large. Meaningful texts are located somewhere in the middle of the entropy scale, with their entropy calculated to be about 1 bit per character.

Next we consider how information is transmitted by natural processes.

Generation of Information by Natural Processes

The following is from an article, "How to Evolve Specified Complexity by Natural Means," by Matt Young, Adjunct Professor of Physics, Colorado School of Mines (Young: 2002). The question of interest is, can natural processes create large quantities of information?

Consider a machine that tosses coins, five at a time. The coins are assumed to be fair and the machine not so precise that its tosses are predictable. Each coin may turn up heads or tails with 50% probability. There are 32 combinations:

HHHHH

HHHHT
HHHTH
HHHTT
and so forth.

The coin tosses are independent of each other, so the total number of permutations is $2^5 = 32$. The exponent, 5, is known as the entropy of the system of five coins. The entropy is the number of bits of data needed to describe the arrangement of the coins after each toss. That is, there is one bit that describes the 1st coin (H or T), one that describes the 2nd (H or T), and so on until the 5th coin has been tossed. In terms of communications transmitted, there are 5 bits altogether from each toss of 5 coins. The entropy of the communication channel, which is a measure of the disorder or uncertainty of the channel over which the information is transmitted, is 5. We gain information as we reduce the entropy. The entropy of the 5 coins arranged randomly is 5; when they are arranged in a specified way, it is 0. The information has increased by 5 bits. Thus, a nonrandom configuration displays less entropy and, therefore, more information than a random configuration.

Meaningful information is not measured in bits and cannot be at all treated using the methods and mathematical tools of information theory. Any random text carries much more information (in the sense of information theory) than any meaningful text of the same length.

Dembski's law of conservation of information states that the number of bits H cannot change in any natural process as a result of either chance or the operation of some physical law. For example, suppose we toss five fair coins in the air. The probability of any specific resulting sequence, say HTTHT, is $(1/2)^5$. The Shannon uncertainty (Dembski information) contained in that sequence is $H = -\log (1/2)^5$.

No information is gained in this random process. Whatever the initial arrangement of the coins prior to their toss, it also contained five bits of information. However, what about a sequence such as HHHHH? Intuitively, it might seem that it contains more information than HTTHT, but it does not. In either case, $H_{after} = H_{before} = 5$ and $R = 0$. However, if we pick two of the coins (Dembski would call it an act of design), $R = 2$ bits of information have been gained.

Suppose the sequence HHHHH is specified in advance. Then we have five bits of what Dembski calls *specified information*. We could just as well have specified HTTHT, as long as we did so ahead of time or identified some other characteristic of the sequence that marked it as something other than a random occurrence. Now five heads in a row, or any specified sequence of five coins, can happen by chance. On average, about one of every 32 tosses of five coins will land with all five heads up. However, suppose we do the experiment with 500 coins instead of five and specify that all fall heads up. This would, on average, require 2500 [the 500 is superscript]= 10150 [the 150 is superscript] tosses of 500 coins each to obtain 500 heads by chance. Dembski rightly says this is, for all practical purposes, impossible, and defines 500 or more bits of information as *complex*. He argues that the observation of *complex specified* information in the universe is evidence for intelligent design. In particular, he holds that biological evolution cannot be the product of chance and natural law.

Dembski does not use the word complexity is its everyday sense nor in any pre-existing technical sense. Instead, he uses it in a misleading sense of his own: complexity is defined to mean improbability. He also uses the word information in the same sense. Further confusion is caused by Dembski's refusal to clarify the improbability to which he is referring. Sometimes he seems to mean the improbability of an event with respect to a specific natural hypothesis, and usually this is a hypothesis involving a uniform probability distribution, such as a hypothesis of purely random combination of components. At other times, he seems to mean that an event is complex if it is improbable with respect to all the natural hypotheses of which we can think. At still other times, he seems to mean that an event is complex if it is improbable with respect to all possible natural causes.

Dembski does not define precisely what he means by specificity. In the coin example above, the sequence is specified in advance. However, he cannot leave it at that because then his whole program to detect design after the fact would be defeated. So, as a dubious alternative, he allows specificity to be post-determined. An observed sequence might contain some message that is too unlikely to have occurred by chance. He uses an example from the film Contact, based on Carl Sagan's novel, in which an intelligent signal from outer space is detected containing the sequence of prime numbers up to 101. Dembski's incorrect claim is that complex specified sequences of information cannot happen naturally.

In information theory, because data transmitted is indifferent to the message, one cannot use the message to point to an intelligent source. This suggests that, whatever the support for ID, the attempt to use evidence from information theory is invalid. Dembski does correctly view any meaningfulness of a string of letters as indicating a high probability of an intelligent author. Of course, to be consistent, he should apply this requirement to biological structures as well as to strings of letters. For example, DNA obviously carries information in nonrandom sequences of the four bases that code genetic information, but there is no way to assert that it carries a message. Thus, to use his own language, how can Dembski determine whether or not the information in DNA is "specified?" Doing so is just an unsubstantiated assumption.

The available data about the structure of DNA indicates that the DNA strand consists of both pieces that carry a genetic code and segments that do not seem to carry any such code. In fact, the human genome is littered with pseudogenes, gene fragments, "orphaned" genes, "junk" DNA, and so many repeated copies of pointless DNA sequences that it cannot be attributed to anything that resembles intelligent design. If we write down the entire genome, we might at first think it has a very high entropy (many bases with many more possible combinations). But once we find out which bases compose genes, we realize that those bases are arranged nonrandomly and that their entropy is close to 0 (or at least very much less than the entropy of an equivalent, random set of bases). That is, the genes contain information because their entropy is less than that of a random sequence of bases of the same length.

Dembski claims to prove that the generation of any information by natural processes and chance is impossible, not just complex specified information. Since the universe contains information, that information must have come about by other means, which he labels intelligent design. While he insists that this argument does not depend on any specific theological assumptions, he often promotes his interpretation that the design inferred is the work of the Christian god. In fact, the whole ID movement is being more than a little disingenuous when it claims that it has no religious agenda.

The Second Law of Thermodynamics and Natural Order

It turns out that the Shannon uncertainty and the physicist's notion of entropy are identical except for a trivial constant, a point that Dembski either does not recognize or chooses to hide. It is well known that entropy is a measure of "disorder." The Shannon uncertainty, as applied in communication theory, is likewise a measure of the disorder in a signal.

In physics, the second law of thermodynamics specifies that, on a macroscopic scale, the entropy of a closed system cannot decrease. Although Dembski does not admit it, his law of conservation of information is nothing more than “conservation of entropy,” a special case of the second law that applies when no dissipative processes are present (which is a rare occurrence in everyday experience). In fact, entropy is created a million times a day by all human beings on earth each time any dissipative processes such as friction are present. “Dembski information” is not conserved in such a simple, natural process.

When Dembski claims that information cannot be generated naturally, he appears to be voicing just another mistaken version of the common creationist assertion that the second law forbids the generation of order by natural processes. Like others, he ignores the fact that the second law refers only to “closed systems.” Open systems can and do become more orderly by their interaction with other systems. For example, as long as the sun provides energy to the earth, we are in an (localized) open system. In the process, both the sun and earth lose entropy; but this is compensated for by a corresponding gain in the total entropy of the expanding universe, which is the closed system for this purpose. The sun provides for the generation of order on earth, including that contained in living organisms. As an example, whenever a drop of water freezes into an ice crystal, we observe the creation of order by a mindless natural process. We don’t need fancy information theory to tell us that. We can see it with our own two eyes. Dembski’s law of conservation of information is not just pseudoscience; it is wrong pseudoscience.

ID advocates ignore another important point: thermodynamic disorder is not the opposite of evolutionary complexity. In some ways, complexity makes life acquire greater entropy. Some of man’s greatest achievements have been in the power-generating sector, which degrades stored potential energy to waste heat. Just as convection currents may develop, complexity in evolution can be related to disorder, not opposed to it. ID advocates are wrong in trying to use the second law and entropy claims as support for their position.

The definition of entropy in information theory is the same as that in thermodynamics, apart from a multiplicative constant. Thus, Dembski’s claim that you cannot increase information beyond a certain limit is equivalent to the claim that you cannot reverse thermodynamic entropy. That claim, often expressed by creationists, is not correct. The correct statement is that you cannot reverse entropy in a closed or isolated system. A living creature is not a closed system. Through continued supplies of thermal energy, living creatures thrive by reversing entropy. As creatures discard waste, the entropy of the universe as a whole increases. Thus, as the universe expands, the maximum entropy that can be contained in its volume increases. The local decrease in entropy is easily compensated for by an entropy increase in the remaining part of the universe. Dembski’s information argument amounts to just another ID ploy to link science to a religious preconception.

Information and Natural Selection

Information in biology has a quality that distinguishes it from information in chemistry and physics. It comes in encoded form and is processed in a way that is closely related to information technology and computer science. Biological information is essentially stored in genotypes and transferred to future generations through inheritance, and less directly through epigenetic processes. Cellular metabolism can be interpreted straightforwardly as information processing. Information is closely related to complexity: more complex things require more information to build and operate.

As an analogy, suppose we have a very large number of coin-tossing machines. These machines toss their coins at irregular intervals. The base of each machine is made of knotty pine, and knots in the pine sometimes leak sap and create a sticky surface. As a result, the coins sometimes stick to the surface and are not tossed when the machine is working. For unknown reasons, machines that have a larger number of heads have a lower probability of malfunctioning. Perhaps the reverse side of the coins is light sensitive, corrodes, and damages the machine. For whatever reason, heads confers an advantage to the machines.

As time goes on, many of the machines malfunction. But sometimes a coin sticks to the knotty pine heads up. A machine with just a few heads permanently showing is "fitter" than those with a few tails permanently showing or those with rapidly changing permutations (because these show tails half the time, on average). Given enough machines and enough time, at least some of the machines will end up with five heads showing. These are the fittest and will survive the longest. Using our previous example of tossing 5 coins at one time, when no coins are stuck on H, the odds are 1 in 32 of tossing all heads (H). But with 2 coins stuck on H, the odds become 1 in 8; with 3 coins stuck on H, the odds become 1 in 4; with 4 coins stuck on H, the odds become 1 in 2; and with all 5 coins stuck on H, the odds are 1 in 1.

It is obvious that, in an analogous sense, the coins represent the genome. If the machines were capable of reproducing, machines with more heads would pass their tendency toward "headedness" to their descendants, and those descendants would out-compete machines that displayed "tailedness." ID advocates argue that there would not be enough time for a complex genome to develop, but they commit the fallacy of assuming that each element in the genome evolves independently of the others. Complexity inside a single-celled organism can increase, for example, when that organism swallows another and incorporates the second organism's genes into its own genome. Alternatively, genes sometimes duplicate and provide separate paths for development. Thus, it is simply not true that a complex genome cannot develop within a billion years or so. With the machines, after a few generations, there would be a preponderance of headedness in their genomes. Thus, we would see a combination of regularity/law (the coin-tossing machines) and chance (coin sticking on H randomly) increasing the information in a genome.

Dembski proposes an "explanatory filter," which is a flow chart designed to distinguish between chance and design. The coin-tossing machines would escape the filter and suggest design where none exists. This is because the filter makes a false dichotomy between chance and design. Natural selection by descent with modification is neither chance nor design but a combination of chance and law. Many self-organizing systems would also pass through Dembski's filter and "prove" design where none exists. ID advocates give short shrift to the self-organization of biological entities, an area where they are most vulnerable. Thus, nonrandom information can be generated by natural causes.

Complex Specified Information and the "747" Argument

To quantify the meaning of specified complexity, Dembski defines complex specified information and nonrandom information as 500 bits or more. He claims that complex specified information could not appear naturally in a finite time and argues that, therefore, life must have been designed.

A favorite argument presented by creationists/ID advocates is that the chance of building a Boeing 747 by tossing the parts into the air and expecting them to fall down as a fully assembled airplane is infinitesimally small. Similarly, as the argument goes, there is only a very small chance of building a complex organism (or, equivalently, a genome) by chance. The analogy is false for at least two reasons:

- Airplanes and mousetraps are assembled from blueprints. The arrangement of the parts is not a matter of chance. In fact, the locations of many of the parts are highly correlated, in the sense that subsystems such as motors are assembled separately from the airplane and incorporated into the airplane as complete units. All mousetraps and airplanes of a given generation are nominally identical. When changes are made, they are expected to be finite and intentional.

- Birds and mice are assembled from recipes, not blueprints. The recipes are passed down with modification and sometimes with error. All birds and mice of a given generation are somewhat different. When changes occur, they are apt to be infinitesimal and accidental.

When Dembski appeals to specified complexity, he is presenting the 747 argument in a different guise. He presents a back-of-the-envelope calculation to “prove” that there has not been enough time for complex specified information to have accumulated in a genome. The calculation implicitly assumes that each bit in the genome is independent of all others and that no two changes can happen simultaneously. The co-option of parts used for one purpose that have been altered for another purpose and the well-known duplication of genes are never considered. Similarly, creationists used to argue that there was not enough time for an eye to develop. A computer simulation by Nilsson and Pelger demonstrated the incorrectness of that claim (Nilsson and Pelger: 1994). They estimated conservatively that 500,000 years was enough time. Even this estimate is likely to be overstated, as the simulation assumed that changes happened in series; in reality, they would almost certainly have happened in parallel, which would have reduced the time required. Similarly, with Dembski’s argument: many changes of the genotype undoubtedly occurred in parallel rather than in series as the naïve probability argument assumes.

It is also the case that there are many possible genomes that might have been successful; minor modifications in a given gene can still yield a workable gene. Dembski ignores all other possibilities, just as he does when he goes along with the assumption that the only possible airplane is the 747. By ignoring all other possible outcomes, he calculates far too low a probability.

To see exactly what Dembski is saying, suppose that there are two manufacturers of jet engines and that they share the market equally. Then, in the absence of further information, we would assume that there is a 50% chance that the engines of the 747 were made by Manufacturer A. By contrast, Dembski would argue that Manufacturer A’s engine has N parts that could have been bought from various subcontractors. He would assign a probability $p(i)$ to each part and calculate the probability $p = p(1) \times p(2) \times ... \times p(N)$ that the engine exists in its present form. Since the engine has many parts, p is a very small number. Dembski would conclude that it is very unlikely that the 747 uses the engine of Manufacturer A. Based on the low probability he would calculate, he would have to conclude that it is extremely unlikely that the 747 had any engine at all.

Summary of Critique of “Law of Conservation of Information”

In assuming that the genome is too complex to have developed in a mere billion years, Dembski propagates the “747” argument. However, organisms did not start out with a long, random genome and then by pure chance rearranged the bases until suddenly Adam appeared among the apes. On the contrary, organisms arguably started with a tiny genome. [How that genome first appeared is another matter; in this article, we are dealing with information theory as related to natural selection by descent with modification, not with the origin of life.]

Evolutionary biologists argue that the genome gradually expanded by well-known mechanisms, such as accidental duplications of genes and incorporation of genomes from other organisms, until it was not only nonrandom, but also complex (certainly containing more than Dembski's limit of 500 bits). In simple terms, if an organism with a 400-bit genome incorporates an organism with a 300-bit genome, the resulting organism has a genome of 700 bits. Similarly, if an organism with a 100-bit genome incorporates five other organisms with 100-bit genomes, the resulting genome has 600 bits. There is nothing to prevent either genome from growing even larger, either in theory or practice. Dembski's law of conservation of information, which is really a law of conservation of complex specified information, can thus be rendered moot as regards an organism's entire genome.

The upshot of the foregoing is that, even if complex specified information (and the 500-bit limit) were a valid concept, it would not apply to the entire genome of an organism but only to specific individual genes or perhaps groups of genes, and then only if it could be shown that the bits in question mutated wholly independently of each other. Furthermore, it is impossible to distinguish whether a specific gene is subject to the 500-bit limit, because the calculation depends on the unknown history of the gene (whether, for example, it contains duplicated segments). Hence, there is no practical difference between specified complexity and nonrandom complexity, i.e., the concept of complex specified information is meaningless unless Dembski can demonstrate that the bits in a given gene mutated independently of each other throughout the history of that gene. Otherwise, the 500-bit limit does not apply.

There is an ethical issue inherent in Dembski's 500-bit criterion for intelligent design. Viruses, which cause tumors and such diseases as smallpox, polio, mumps, hepatitis-A, influenza, AIDS, etc.; oncogenes and proto-oncogenes, which are cancer genes; and "jumping genes" or mobile elements, which cause havoc in our genome, all may exceed the 500-bit limit. [Genome size of viruses range from 5000 base pairs or 5 genes (Simian virus 40), and 9752 base pairs or 9 genes (HIV), up to 230,000 base pairs or 230 genes (herpes viruses).] So there are many viruses, small and large, that equal or exceed the information content of organisms that generate complex specified information. Thus, if Dembski claims intelligent design for all genes greater than 500 bits, he cannot deny intelligent design for viruses, oncogenes, and mobile elements (Korthof : 2002). Such designs raise questions about the wisdom and/or good will of the designer. Dembski is "hoisted on his own petard."

Conclusion

Dembski's information theory argument is little more than the old creationist misinterpretation of the second law of thermodynamics. Sequences of complex specified information can be generated naturally and happen every day. Dembski's notion of complex specified information is a smokescreen behind which to hide a misapplication of information theory.

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