

GENERAL SCIENCE NOTE

DETECTING DESIGN IN NATURE

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Speculation about extraterrestrial aliens has gone on for a long time; at least 2,000 years. Titus Lucretius Carus was an early proponent of extraterrestrial life. Around 55 BC he wrote:

*...it cannot by any means be thought likely that this is the only round earth and sky that has been made,...since this world was made by nature, and the seeds of things themselves of their own accord...could become in each case the beginnings of mighty things, of earth and sea and sky and the generation of living creatures. Therefore again and again I say, you must confess that there are other assemblages of matter in other places, such as this is which the ether holds in greedy embrace.*¹

Lucretius is thought to be reflecting the earlier thoughts of Epicurus who also appears to have believed in extraterrestrial life.²

The problem with speculation about extraterrestrial life is that if such life exists, it is extraterrestrial, making it hard to study from here on earth. The best that we can do from our terrestrial vantage point is to look for signs of life on other planets. These signs can fall into two categories: 1) evidence that conditions essential for life are present and 2) direct evidence of the activity of living things. Recently there has been much excitement over data collected by the Mars Odyssey spacecraft that seems to indicate hydrogen on the surface of Mars. This hydrogen is thought to be in water molecules and water is essential for life.³ If water is present on Mars, one condition for life is met, but it does not prove that all conditions necessary for life are present on Mars.

Finding direct evidence of extraterrestrial life may be more difficult than finding conditions conducive to life, but this has not stopped scientists from looking. A recent example might be discovery of carbonyl sulfide in the atmosphere of Venus.⁴ Inorganic production of carbonyl sulfide may be difficult while its production by organisms is known.⁵ Thus, presence of carbonyl sulfide may be viewed as possible evidence of the activity of organisms.

Signs of life are well understood and may be employed when searching for life on other planets. On the other hand, searching for intelligent life may be a more complex challenge. Signs of intelligence should be detectable in the same way that signs of life are detectable. Like signs of life, signs of intelligence can be divided into two categories: 1) Data not typical of natural processes and 2) data known to be the product of intelligence. In one sense, separation of these two categories of data is artificial, as many data known to be products of intelligence are also atypical of natural processes.

Before data can be categorized as atypical of natural processes, natural processes must be identified. In other words, the tools by which nature works must be known and understood before limits can be put on what nature can accomplish. The history of science is a record of humanity's success in understanding how nature works. In general two tools are known to be used by nature: 1) A set of laws governing the interaction of matter and 2) chance, which determines where, when, and under what conditions matter interacts with other matter.

Gravity is an example of a law governing interactions between matter. In essence it is a simple law stating that bodies with mass are attracted to one another. But when combined with other simple laws gravity accounts for the apparently complex interaction of planets within our solar system and our solar system with the rest of the universe. Sometimes the products of simple laws of nature are elegant and ordered. For example, the structure of crystals is very ordered, but arises from the relatively simple interaction of positive and negative charges; like positively charged sodium (Na^+) and negatively charged chloride (Cl^-) to form table salt crystals.

Gravity is an impressive law of nature and, like other laws, it may be employed by intelligent beings for specific purposes. For example, farmers in some parts of England have removed rocks from their fields and stacked them into dry stone walls which now divide much of the British countryside into a checkerboard of cultivated fields. These walls serve important purposes including delineation of property lines and separation of livestock from fields in which crops are being grown.⁶ This purpose is facilitated by gravity, which prevents the rocks from floating away, but gravity is not responsible for the purpose. This is evident from the observation that gravity held the very same rocks in position in the fields before farmers came to work them. It took the intelligently directed efforts of farmers to move the rocks and arrange

them so that they now serve a purpose or function. If viewed from space, these rock walls immediately suggest the presence of intelligent design, as nature is not known to arrange rocks in long rows stacked as they are in dry stone walls. In addition, purpose is evident and thus intelligence is logically inferred from the presence of these walls. Dry stone walls in the northeastern United States or southeastern Australia also suggest intelligent causes; the location of the walls doesn't matter. It is the presence of purpose and lack of known natural causes that suggests intelligent design.

Like dry stone walls, canals may also exhibit the characteristics of intelligently designed objects: structures not known to be naturally caused and exhibiting some kind of purpose. The network of canals that crisscrosses the United Kingdom exhibits these characteristics. Structurally they tend to be straight and to slope very gently if at all. Locks, clearly not a natural feature, control movement of water in the system. A map of the canal system reveals that they go between population centers suggesting their purpose as highways for transportation of materials. The great astronomer Percival Lowell, thinking he saw canals on Mars, immediately interpreted their presence as an indicator of intelligent life there. When better telescopes revealed only features known to be the products of nature, most people abandoned Lowell's life-on-Mars theory.⁷

It was not because Lowell was a bad scientist that he concluded life existed on Mars; the error was in the poor data with which he had to work. What Lowell thought he saw were structures that functioned (moving or holding water) as part of a larger system. To function in the large system of interconnected canals, each individual canal conformed to specified criteria. For example, they had to connect with other canals and be large enough to hold or carry significant quantities of liquid. In other words, the structures Lowell thought he saw on Mars had an obvious purpose and were unlikely to be the product of chance coupled with natural law; so he concluded they must have been designed by intelligent Martians. Inference from purpose to design is logical and within the realm of science. This is what forensic science and archaeology do routinely. Data are collected and examined. If they indicate the characteristics of intelligent design, then some intelligent agent is logically inferred. For example, when flint arrowheads are discovered, they are interpreted as the product of some intelligent being, not nature or some kind of magic. In searching for intelligence scientists routinely

look for patterns different from those produced by nature, and for purpose. Using this kind of logic, The Search for ExtraTerrestrial Intelligence (SETI) filters radio signals from space looking for patterns reflecting intelligence.⁸

So far we have established that there are principles for detection of intelligent design just as there are principles for detection of life. In addition, scientists routinely use these principles to detect the activity of intelligent beings in the past and present. However, a semantic trap may exist for those who seek to detect design in nature. The problem arises when we are attempting to delineate between the natural and the artificial. Defining nature as the product of natural causes while artificial things, like stone walls, are the product of intelligent causes appears to be logical. Taking nature, defined as a product of natural causes, and studying it to determine whether it is the product of intelligent design seems preposterous as it is by definition natural and not artificial. Clearly a different set of criteria needs to be created to allow for the delineation of products of natural laws and intelligent design.

This brings us back to the dry stone walls discussed earlier. The walls operate (remain functional) as a result of at least one natural law — gravity — but they came into existence as a result of intelligent design. Would living things still be part of nature if they operated in the same way, having been produced by a process involving intelligent design, but now operating according to natural laws? A way around questions of this sort is to simply define life as natural and demand that only natural explanations be employed when explaining it. An example of this would be: “Scientific knowledge is limited to natural explanations for natural phenomena based on evidence from our senses or technological extensions.”⁹ But this creates a kind of circular reasoning in which phenomena like life, if they are considered to be natural, may only be explained as the result of natural forces and chance and thus natural forces and chance must be sufficient to explain all natural phenomena whether this seems reasonable or not.

What if a scientist didn’t already know that dry stone walls are the result of intelligent action? They are pervasive in the British Isles and many other places; many lack a historical record of when they were made and by whom. What if the walls were mistakenly categorized as a natural part of the English landscape? Once they were categorized as natural, only natural explanations would be allowed to account for their origin and if natural explanations are by definition sufficient to account

for all of nature, then they must be sufficient to account for the origin of walls. Once they are categorized as “natural,” then there can be no way of ever showing that dry stone walls were the product of intelligently directed effort by generations of farmers. Restricting science to natural explanations creates a reasonable expectation that it will attribute properties to nature that nature may in reality lack and that phenomena mistakenly categorized as natural will continue to be mis-categorized, further skewing our understanding of how nature works.

The only way science can determine whether dry stone walls are the product of natural or intelligently driven processes is by allowing the possibility of intelligent beings who played a role in production of the walls. Once intelligent causes are allowed, science can evaluate the evidence, determine whether or not walls meet the criteria for intelligent design and draw logical conclusions. Without allowing the possibility of intelligence, the science of studying walls becomes dogmatic. The same is true when studying life or other phenomena.

If a determination is to be made about whether life is a product of intelligent or natural causes, the possibility of intelligent design cannot be forbidden before the investigation begins. But this raises again the problem of what is natural versus what is artificial. If nature is not natural it can hardly be nature. On the other hand, even artificial devices like machines operate according to natural laws and not magic. Once they are made, dry stone walls are as natural as any other pile of rocks; what makes them unnatural is the fact that something beyond the normal blind actions of nature was responsible for the arrangement of the rocks. One way around this problem is to allow something outside of nature to have acted on nature at some point. This avoids arbitrarily constraining the possible answers before addressing the question of intelligent design in nature. When applied to living systems, this would mean that they could have been acted on by an intelligence outside of nature: something supernatural.

Why should intelligent beings just as natural as humans be ruled out as the ultimate source of intelligent design in nature?¹⁰ The problem with this explanation is that the problem is pushed back without actually being addressed. Humans are the most intelligent beings known and they exhibit characteristics of intelligent design. If human intelligence is dependent on intelligent design, it hardly seems reasonable to suppose that other intelligent creatures are not dependent on an intelligent cause for their intelligence. Ultimately intelligence outside of nature is

necessary to account for intelligent design in nature. Just as something outside of the elements and laws governing their interaction is required to account for intelligent arrangement of rocks into a wall, intelligence in nature that is dependent on intelligent design requires an ultimate intelligent cause outside of nature. Who or what caused this supernatural intelligence? As long as we live in the natural world, we will probably have no basis for investigating this question, but this is not a logical reason to rule out the possibility of a supernatural intelligence.

To determine whether intelligent design can be inferred from data in nature we have established the need for allowing the possibility of an intelligence outside of nature and development of criteria for judging between natural and intelligent causes. Ultimately this is true whether intelligent design is evident in nature or not. The history of evolutionary thought illustrates this need. For example, Lucretius argued.

*The nature of the universe confirms it cannot have been created for us by divine power: it has so many faults.*¹¹

To argue against a supernatural origin of the universe Lucretius must first allow that the supernatural can be discussed and then show that criteria he has set — e.g., any imperfection precludes supernatural involvement — are logical, reasonable and have not been met. The argument from imperfection used by Lucretius has been recycled many times by more recent authors, for example, when arguing against a supernatural role in the creation of life Stephen J. Gould wrote:

*Imperfection carries the day [over divine creation] for evolution.*¹²

The important point is not the questionable nature of the criteria used to rule out the supernatural, but that supernatural involvement in the origin of life may be logically discussed on the basis of natural phenomena. These examples show the necessity of including the supernatural or divine as one possibility if design — specifically intelligent design — or its absence, is to be investigated in nature. It seems unreasonable to restrict investigation of supernatural involvement in the origin of life to only one possible answer before the question is resolved. In addition, Lucretius and Gould show that discussion of intelligent design in nature has continued from ancient times to the present.

The philosopher and mathematician William Dembski has formalized the criteria listed earlier for determining whether intelligence was involved in production of specific phenomena.¹³ Dembski avoids the

term “purpose” as this may require the observer to get into the mind of the designer. Instead he uses the terms “specification” and “probability.” Specification refers to patterns that satisfy certain precise logico-mathematical conditions including phenomena that vary independently, but work together within fine tolerances. For example, the cylinders and pistons in an internal combustion engine exhibit specification because the iron from which they are formed may be molded into almost any conceivable shape, but they just happen to fit together in such a way that engines work. There is no natural law that causes iron to form cylinders or pistons or dictates that they should fit to a tolerance of several micrometers. Thus the probability of nature producing pistons and cylinders that fit correctly is very low. Pistons and cylinders fit together because they were designed to do so by intelligent engineers, they clearly are not a product of chance and natural laws.

As it turns out, much of nature exhibits the characteristics of intelligent design, whether informally stated as apparent purpose or more formally stated as specification and small probability. Many biologists have noted this appearance of purpose. For example, George Gaylord Simpson (one of the fathers of neodarwinism) wrote:

*This appearance of purposefulness is pervading in nature, in the general structure of animals and plants, in the mechanisms of their various organs, and in the give and take of their relationships with each other. Accounting for this apparent purposefulness is a basic problem for any system of philosophy or of science.*¹⁴

This appearance of purpose is especially true of life at the molecular level and the language of design is frequently used when describing molecular machines and information. After publication of the human genome, Gene Meyers, who designed software used in the project, didn't hesitate to use the language of design to describe what they had discovered in the project:

*What really astounds me is the architecture of life...The system is extremely complex. It's like it was designed....There's a huge intelligence there. I don't see that as being unscientific. Others may, but not me.*¹⁵

One criticism of those who claim to see design in nature is that they are not qualified to recognize design, but in the case of Gene Meyers, this argument cannot be made. As a designer of software he is

clearly in a position to recognize design. His involvement with the Human Genome Project qualifies him to discuss information in the genome. Biologists are, in general, less qualified to recognize design, and yet they may still intuitively suspect that what they study is designed. Nobel Prize winner Francis Crick, codiscoverer of the double-helical structure of DNA, warned:

*Biologists must constantly keep in mind that what they see was not designed, but rather evolved.*¹⁶

But why should biologists avoid the conclusion that the object of their study was designed? If something as simple as a dry stone wall can be accepted as a product of intelligent design, why should something as complex as the human genome, or a single cell, or even the molecular machines from which they are made not be viewed as designed?

Stephen Pinker, professor of psychology at the Massachusetts Institute of Technology, provides the answer to these questions when he writes:

*Our conclusion is based on two facts that we would think would be entirely uncontroversial: language shows signs of complex design for the communication of propositional structures, and the only explanation for the origin of organs with complex design is the process of natural selection.*¹⁷

Pinker recognizes the signs of design in language, but allows only one explanation, the law he refers to as natural selection. Like other laws, natural selection is a phenomenon that can be studied in nature and thus its role in production and maintenance of natural phenomena can be elucidated. When discussing the law of gravity and dry stone walls, it was clear that gravity could not account for the production of the walls, but it did function in maintaining the wall by preventing stones from floating away into space. In a general sense it is possible for laws to be real and to function in the maintenance of structures while not accounting for their origin. Pinker attributes the origin of language, an activity of living things, to natural selection. Is it possible, in a general sense, for natural selection to account for the information and machines found at the molecular level in organisms?

Charles Darwin suggested that natural selection is sufficient if certain criteria are met:

If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous,

*successive, slight modifications, my theory would absolutely break down.*¹⁸

Darwin limited the work of natural selection to very small steps. This is because to be selected, a trait has to increase fitness and large changes are unlikely to increase fitness. Michael Behe has discussed the implications of this limitation at length.¹⁹ The requirement that all vital components of living systems evolve in small steps and the need that every step be adaptive if it is to spread through populations places important limits on what natural selection can achieve. To determine whether systems found in living things are potentially the product of natural causes — the law of natural selection combined with chance events — requires that the molecules from which living things are composed be caused by natural laws.

This is a challenging determination to make. One difficulty is selection of molecules to examine that will inform the question. Most organisms are composed primarily of water and water is clearly a product of natural laws. Life is not required for production of water, oxygen reacts spontaneously with hydrogen to produce it. Proteins are clearly essential for life, but proteins are composed of amino acids. As long ago as 1953²⁰ Stanley Miller and Harold Urey conducted experiments showing that some amino acids can be produced independently of any apparent direct intelligent input (although the machine they used to create amino acids in was clearly a cleverly constructed device). Natural laws and chance are sufficient for production of some amino acids. It may even be possible to join amino acids together under abiotic conditions and this has been demonstrated in a very limited way.²¹ None of the chemical bonds that holds the various atoms together in protein molecules is uniquely different from those found outside of living systems. What is unique to living systems is the specific ordering of amino acids in proteins. The order of amino acids, in combination with special protein folding molecular machines, ultimately determines the specific complex shape necessary for proteins to achieve their functional purpose. In other words all those natural laws that hold proteins together can be accounted for by nature. However, natural chemical laws do not account for the specific sequences in which amino acids are joined together. Again, the dry-stone-wall analogy applies. Natural laws account for the way the wall functions and hold it together, but they do not account for the origin of the wall in the first place.

Can natural selection account for the sequence of amino acids in a protein? This is the specific claim of those who believe intelligent design is not evident in living things. At best the laws of chemistry seem only capable of joining amino acids together, but not in any biologically meaningful order. To gain meaning in the first place requires either intelligent input or incredible chance. Once a protein has a functional purpose, and it is part of a reproducing system, it may be possible to hone that function by random mutation of the protein's amino acid sequence coupled with natural selection of those changes that improve the fitness of the organism. The question is, does this require only "slight modifications" as Darwin suggested?

The simple answer to this question is no. This is because many proteins vital to life do not function on their own. Proteins commonly work in combination with other proteins. The protein Glyceraldehyde-3-Phosphate Dehydrogenase (G3P Dehydrogenase) illustrates this point. G3P Dehydrogenase is an enzyme that functions as part of the glycolytic biochemical pathway, a molecular assembly line breaking down sugar and releasing energy. All cells have this glycolytic pathway. The pathway has 10 steps and G3P Dehydrogenase functions at step 6. In the absence of the other steps, G3P Dehydrogenase would still be an impressively complex protein, but it would serve no purpose as it would have no substrate on which to work and the products of the chemical reaction it catalyzes would have no use. If it had no purpose, natural selection would not be able to act on slight modifications in G3P Dehydrogenase as the modifications would also have no purpose and thus they would not contribute in any way to the fitness of the organism. Once G3P Dehydrogenase has a functional role, modifications that diminish its function would decrease fitness while any modifications that improve function could increase fitness, but function must first be present for selection to operate.

Getting functional G3P Dehydrogenase using chance combinations of amino acids is a vanishingly small proposition.²² Producing all 10 enzymes that make up the glycolytic pathway of which G3P Dehydrogenase is part is not a slight modification, it is the sort of giant leap that nature is not known to do. In short G3P Dehydrogenase is one example of thousands that could be offered which demonstrate the inability of natural selection combined with chance to produce living things. Natural selection may be an important law of nature that maintains organisms over long periods of time, but just as gravity cannot make a dry stone

wall, natural selection cannot make functional proteins that are vital to the existence of living things.

Proteins at the core of living systems do not appear to be the product of known natural laws. This was one of the two criteria set up earlier for detecting products of intelligent design. The other criterion was that the data being examined fit the pattern of those things known to be the product of intelligence. In the case of G3P Dehydrogenase this property also is evident. Intelligence is known to produce purposefully ordered sequences in circumstances other than proteins. For example intelligent humans order letters in specific sequences for the purpose of conveying meaning. Meaning is the purpose of ordering letters into words just as function is the purpose of the ordering of amino acids in proteins. Nature is not known to produce meaningful ordering of letters, or chemicals, but intelligence is known to order things in meaningful ways. Thus the functional ordering of amino acids in G3P Dehydrogenase can be logically accounted for by some intelligent design taking advantage of the laws by which chemicals interact for the ultimate purpose of creating functional parts of the complex assemblages of machines that make up living systems. Physical laws allow proteins to function, but intelligent design accounts for their origin.

Many excellent examples of intelligent design exist at the molecular level, but it is not just at this level that life exhibits purpose. As Sir Julian Huxley, one of the fathers of modern Darwinism, put it:

*At first sight the biological sector seems full of purpose. Organisms are built as if purposefully designed, and work as if in purposeful pursuit of a conscious aim. But the truth lies in those two words 'as if'. As the genius of Darwin showed, the purpose is only an apparent one.*²³

Purpose, a hallmark of intelligent design, is evident in nature at many levels. Huxley wrote when our understanding of the molecular makeup of cells was sketchy at best. Now that the molecular workings of cells are better understood, the inadequacy of Darwin's naturalistic explanation has become obvious. This leaves us with no positive natural explanation for what we see in living things and a positive argument for design in nature. In short, as long as a supernatural Intelligent Designer is allowed as a potential cause for life, intelligent design can be studied in nature and in fact is evident.

ENDNOTES

1. Titus Lucretius Carus. c. 55 BC *De Rerum Natura*, book 2, lines 1,055-1066, translated by W. H. D. Rouse. In: Rouse WHD. 1992. *Lucretius De Rerum Natura*. Cambridge, MA: Harvard University Press, p 178-179.
2. Unfortunately most of the writings of Epicurus have been lost. The best available source is probably book 10 of *Philosophoi Biol* (Lives of Eminent Philosophers) by Diogenes Laertius written c. 230 AD. In this book Laertius reproduces several works by Epicurus including letters to Herodotus and Pythocles in which he seems to infer the presence of other worlds.
3. Boynton WV, Feldman WC, Squyres SW, Prettyman TH, Bruckner J, Evans LG, Reedy RC, Starr R, Arnold JR, Drake DM, Englert PA, Metzger AE, Mitrofanov I, Trombka JJ, D'Uston C, Wanke H, Gasnault O, Hamara DK, Janes DM, Marcialis RL, Maurice S, Mikheeva I, Taylor GJ, Tokar R, Shinohara C. 2002. Distribution of hydrogen in the near surface of Mars: evidence for subsurface ice deposits. *Science* 297(5578):81-85.
4. Schulze-Makuch D, Irwin LN. 2002 Reassessing the possibility of life on Venus: proposal for an astrobiology mission. *Astrobiology* 2(2):197-202.
5. There does not seem to be general agreement about how difficult it is to produce carbonyl sulfide. For example, see: Leman L, Orgel L, Ghadiri MR. 2004. Carbonyl sulfide-mediated prebiotic formation of peptides. *Science* 306:282-286.
6. Hooker J. 1995. 'Stone Walls in Western Victoria', in: *If These Walls Could Talk*, a report or the Corangamite Dry Stone Walls Project. Corangamite Arts Council, p 61.
7. The text of Lowell's book, entitled *Mars*, is available at: <http://www.bibliomania.com/2/1/69/116/frameset.html>.
8. The best source of information on SETI is the SETI web site at <http://www.seti.org/>. The SETI strategy for detection of extraterrestrial intelligence is outlined in: Ekers R, Cullers K, Billingham J, Scheffer L. 2002. *SETI 2020: a roadmap for the search for extraterrestrial intelligence*. Mountain View, CA: SETI Press. 551 p.
9. This definition comes from proposed Ohio State Science Standards 2001 entitled *Scientific Ways of Knowing*, Grade 10, Indicator 3. In the final voted standards, this standard was changed to take a neutral stance on explanations available to science.
10. This theory is sometimes called "directed panspermia." An example of the arguments made for this theory can be found in: Crick F. 1981. *Life itself*. Riverside, NJ: Simon & Schuster. 192 pages.
11. My own interpretation of "Nequaquam nobis divinitus esse paratam Naturam rerum: tanta stat praedita culpa", Titus Lucretius Carus, c. 55 BC. *De Rerum Natura*, book 2, lines 180-181, translated by W. H. D. Rouse. In: Rouse 1992, p 108 (see Endnote 1).
12. Gould SJ. 1980. *The panda's thumb: more reflections on natural history*. NY: W. W. Norton, p 37.
13. Probably the most accessible and concise summary of Dembski's thinking is contained in: (a) Dembski WA. 1998. *Redesigning science*. In: Dembski WA, editor. *Mere Creation*. Downers Grove, IL: InterVarsity Press, p 93-112. More detailed discussions can be found in: (b) Dembski WA. 1999. *Intelligent Design: the bridge between science and theology*. Downers Grove, IL: InterVarsity Press; (c) Dembski WA. 1998. *The design inference: eliminating chance through small probabilities* (Cambridge Studies in Probability, Induction and Decision Theory). NY: Cambridge University Press; (d) Dembski WA. 2001. *Signs of intelligence: understanding Intelligent Design*. Grand Rapids, MI: Brazos Press; (e) Dembski WA. 2001. *No free lunch: why specified complexity cannot be purchased without intelligence*. Lanham, MD: Rowman & Littlefield.
14. Simpson GG. 1947. *Plan and purpose in nature*. *Scientific Monthly* 64:481-495, reprinted in: Simpson GG. 1964. *This view of life: the world of an evolutionist*. NY: Harcourt, Brace & World, p 191.

15. Gene Myers, designer of software used to reconstruct the human genome from sequenced fragments at Celera Corp. Quoted in: Abate T. 2001. Human genome map has scientists talking about the divine: surprisingly low number of genes raises big questions. *San Francisco Chronicle*, February 19, 2001. <http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2001/02/19/BU141026.DTL>.
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19. Behe M. 1996. Darwin's black box: the biochemical challenge to evolution. NY: Free Press,
20. Miller SL. Production of amino acids under possible primitive earth conditions. *Science* 117:528-529.
21. Imai E, Honda H, Hatori K, Brack A, Matsuno K. 1999. Elongation of oligopeptides in a simulated submarine hydrothermal system. *Science* 283:831-833.
22. Determination of the probability of producing a given protein under prebiotic conditions on earth using only chance and the laws of nature is currently impossible. This is because the variables – relative amino acid concentrations, conditions for production of bonds between amino acids and so on – necessary to insert in any calculation are unknown. A feel for the probability may be possible if certain assumptions are made. *Mycoplasma genitalium* is among the simplest known living things. In the case of its G3P Dehydrogenase, there are 337 precisely ordered amino acids. Assuming that conditions exist under which long chains of amino acids are formed and that amino acids are incorporated both randomly and with equal probability, the probability of generating *Mycoplasma* G3P would be $(1/20)^{337}$ which is 3.5×10^{-439} ; essentially zero.
23. Huxley JS. 1953. Evolution in action. Harmondsworth, Middlesex, UK: Penguin (1963 reprint), p 16.