

The Design Isomorph and Isomorphic Complexity

A design-based perspective for biological research emerges from the evidence, history, and methods of studying life

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Abstract. From its beginnings, the empirical study of life has been earmarked by the idea that tiny machines are at work in living tissues. The discovery of protein machines and the illumination of the genetic code during the 20th century revealed a profound similarity between many aspects of technological devices and biological components, and this fulfilled many of the musings of early biological thinkers. The stronger similarities between biology and engineering are so clear that there are pervasive cases of *design isomorphs*, where precise technological designs are found to preexist in living organisms. This isomorphic congruence has been thought by many to be a mere coincidental outcome of undirected evolutionary processes, making the similarities superfluous to scientific practice, and inconsequential to the question of the cause of life. The precision of the likenesses might suggest a reevaluation of viewing the matches as uncorrelated coincidences. Conceptual likenesses are widespread, and exist at all levels of organismal complexity. Cases of *isomorphic reasoning*, when the similarities between machine devices and organism parts have been applied to experimental biology, reveal a powerful conceptual resource for the research biologist. Cooperation between biologists and technologists in *isomorphic integration* yields a successful investigative effort of previously unknown efficiency. The rendering of a quantitative metric of isomorphic relationships, presented here as *Isomorphic Complexity* (abbreviated IsoC), would bring the possibility of a database that could be queried for possible help in biological and technological research. One might get the distinct impression that something more than mere coincidence is involved in the origin of the isomorphic connection between organic biology and teleological machines.

Keywords: history of biology, design isomorph, complete isomorph, isomorphic reasoning, isomorphic integration, isomorphic complexity

Introduction

Biophysicist Robert Eisenberg wrote that, “Productive research is catalysed by assuming that most biological systems are devices. Thinking today of your biological preparation as a device tells you what experiments to do tomorrow.”¹ Why might this be good advice for a biologist? As the reader digests this paper, it will become clear that it is good counsel for the research biologist to draw from technological and teleological concepts to understand biology.

A connection between organisms and machines has been present in the study of how living things work from its inception to the present day.² Modern medicine had similar concepts from its beginning to its current form. With the industrial age in the historical rearview mirror and the information age fast approaching, Michael Polanyi gave a thought provoking outline of the striking similarities between an organism and a machine that occur at the most fundamental levels of their forms.³ Biological reasoning is often based on the idea that organic machines underlie biological function, and that these operations are explained by similar laws and principles to those operating in teleological and technological devices. It has now been realized that the connection between biological systems and engineered systems is far stronger than previously thought.⁴

Like many past and present thinkers that have contributed to biology and technology, this paper will focus on specific similarities, while the relevant differences for such applications will be left to other existing and future works. This is done in order to seek possible benefits to the life and applied sciences that might issue from concepts presented here.

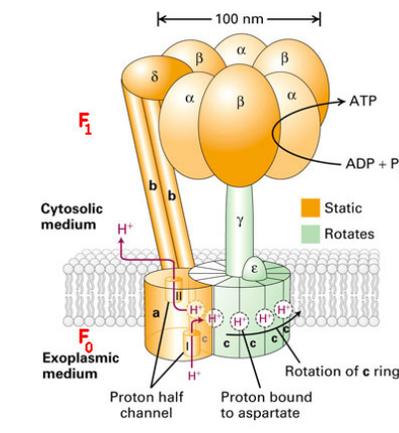
Figure 1.1

Motors, stators, axles and rotors are wheel-based designs that transfer or transform energy in a rotational manner. These designs are found in electric motors (top picture) and in ATPase (bottom picture).

Technological motor



Biological motor (subcellular)



The design isomorph

Likenesses between biology and technology have been discussed in other works,⁵ but now the progress of the life and applied sciences have, with greater clarity and more data, revealed to our eyes a surprising fact. Similarities can manifest themselves as specific cases called design isomorphs, where a technological design is found to exist in living things. (For examples of design isomorphs with illustrations and descriptions, see Figures 1.1 – 1.6.) LEDs, rotors, bushings, worm gear, compasses, levers, flight technologies, codes, circuitry motifs, clutches, logic gates, and network configuration regimes are but a few examples of design isomorphs. As it turns out, the physical structures of design isomorphs are very similar in form and function, or exactly the same in design and purpose. The isomorphic link between biology and technology is much tighter than Pierre Gassendi and other early scientific thinkers could have ever imagined.

Types of Isomorphs

There are four main types of isomorphic correlations between technology and biology: *conceptual*, *functional*, *material*, and *structural*. In *conceptual iso-*

¹ Robert Eisenberg. 2007. “Look at biological systems through an engineer’s eyes.” *Nature* 447:376.

² Marco Piccolino. 2000. “Biological machines: from mills to molecules.” *Nature Reviews Molecular Cell Biology* 1. Nov. 2000, pp. 149-153.

³ Michael Polanyi. 1968. “Life’s Irreducible Structure.” *Science* 160 (3834), Jun. 21, 1968, pp. 1308-1312.

⁴ Marie Csete and John Doyle. 2002. “Reverse Engineering of Biological Complexity.” *Science* 295, 1 March 2002, pp. 1664-1669.

⁵ For example: Steven Vogel. 1998. *Cats’ Paws and Catapults: Mechanical Worlds of Nature and People*. Norton.

morphs, the stratagems or plans are related by the same ideas. *Functional isomorphs* are similarities related to the goal or purpose that is brought about by the arrangement of parts. *Structural isomorphs* have matching physical configurations. *Material isomorphs* use similar elements, molecules, or substrate material in the operation of an isomorphic concept or function. These types are a “ground floor,” upon which other derived varieties of isomorphic relationships occur.

Other derived varieties of isomorphs

It is often the case that design isomorphs utilize different combinations of types, having more than one type, and so being derivative of the above basic types. An isomorph that mirrors all four of the above types is a *complete isomorph*. A *layered isomorph* is a unified complex structure that has matches at multiple levels for different functions. A *cooperative isomorph* is when multiple non-unified isomorphic structures are working together within a system to perform one function. An *organismal isomorph* is when the whole organism is involved with the conceptual or functional isomorph.

Of discoveries to date, usage of a conceptual or a functional design is the most frequent type of isomorph, and these often have exact matches between cases of technological use and biological use.

Examples of complete isomorphs can be found in species of magnetotactic bacteria. These species of bacteria use magnetized components of their cells, appropriately called magnetosomes, as compasses to navigate.⁶ These organisms have the ability to “ori-

entate and navigate along geomagnetic lines,” and this aptitude “is due to intracellular magnetic particles.” Current data indicates that half of a magnetosome chain is passed on from the parent cells, but the other half is formed by mineral-uptake systems.⁷ Derived varieties of isomorphic relationships are at work in magnetotactic bacteria, beyond the fact that the isomorphic relationship in magnetotactic bacteria holds strong on all four basic isomorphic types. Magnetically guided bacteria are an organismal isomorph,

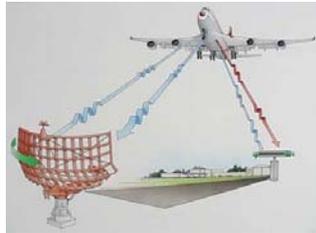
since the processes of motion involved in magnetotaxis depend on aspects of the entire organism. Magnetotactic bacteria that utilize flagellar motility show signs of being cooperative isomorphs, since the magnetosomes and the flagellar assemblies would each have their own obvious isomorphic connections.

The isomorphic relationship between organisms and inventions can also hold for one, two, or three types. For example, a *two-way isomorph* is found with open and alternate reading frames in the base pairs of DNA and RNA.⁸ These are conceptually related to Caesar ciphers since both are data streams. The functional tie-in is a closer match still with two messages of different meanings in one data stream. Yet, material and structural similarities are not typically comparable, since the material substrate of DNA are sugars and phosphates, whereas letters are most commonly found on instances of ink-and-paper or bytes in computer storage devices.

Figure 1.2

Echolocation utilizes a signal bounced off an object to receive data about the object. Echolocation is used in radar devices, sonar devices, and by bats for flight navigation at night and to locate prey.

Tech. echolocation



Bio. echolocation (organ system)



⁶ Lins de Barros HG, Esquivel DM, Farina M. 1990. “Magnetotaxis.” *Science Progress*. 1990;74(295 Pt 3):347-59. Balkwill DL, Maratea D, Blakemore RP. 1980. “Ultrastructure of a Magnetotactic Spirillum.”

Journal of Bacteriology, Vol. 141, No. 3, Mar. 1980, p. 1399-1408.

⁷ Arash Komeili. 2007. “Molecular Mechanisms of Magnetosome Formation.” *Annual Review of Biochemistry* 76, pp. 351–66.

⁸ Wen-Yu Chung, Samir Wadhawan, et al. 2007. “A First Look at AR-Fome: Dual-Coding Genes in Mammalian Genomes.” *PLoS Computational Biology*, 3:5:e91. 1 May 2007.

The three-way isomorph can be explained further using the example of the advanced design of high-efficiency LEDs, which were developed for electronic devices⁹ and later found in a species of African swallowtail butterflies.¹⁰ That is to say, LEDs in technology and biology are conceptually the same (being a semiconductor diode), have the same function (serve the purpose of more efficiently using light), and are structurally the same (sharing the same basic shape and form including structures serving as photonic-crystals and distributed Bragg reflectors).

Two examples of a layered isomorph are the DNA double helix and the bacterial flagellum. The structure of the DNA molecule allows for different types of functions. The spiral-shaped double helix allows for functionality like a worm-wheel when the DNA is coupled to the helicase, the chain of nucleic acids serves as sequence codes while also bonding and serving as spokes or spines, and the structure also allows for function like a zipper for replication and transcription. All of these functions are concurrently dependent on the molecular structure of DNA. Some bacterial flagellum has many isomorphic connections, including rotors, stators, engines, and even a clutch.¹¹

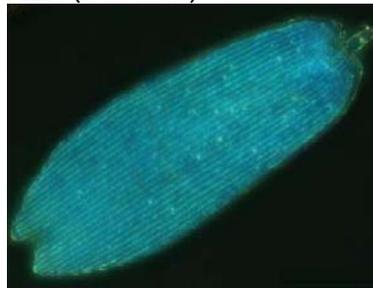
Figure 1.3

LEDs (light emitting diodes) are semiconductors that emit light with remarkable efficiency. High-efficiency LEDs can be found in electronic devices and in one special species of butterfly. (see Vukusic footnote)

Tech. LEDs



Bio. LEDs (intercellular)



Design isomorphs and scientific practice

The biological insights disclosed by scholars like Michael Polanyi and Erwin Schrödinger¹² state that life operates within the fundamental aspects of nature as identified by physics and chemistry, but that life is not reducible to the laws of physics and chemistry alone. One aspect of this irreducibility is the sequence code formed by successive nucleic acid base pairs in DNA, and the successive amino acid structure of a protein, are not determined by the properties of their chemical parts. Genetic diversity is constrained by physical and chemical qualities of nucleic acids, but do not determine the sequences of base pairs. If life is not reducible to physics and chemistry alone, and cannot be completely understood in purely physico-chemical terms, how should it be studied and how can it be understood?

Intelligent design (ID) proposes that life shows the telltale signs

of being designed by intelligence, and if this were true it would follow that certain features will be better studied as a type of intelligent design. If the inference that life was caused by intelligence is correct, there should be a link between biology and technology. There should be specific instances where organisms would be better investigated as if they were inventions of human technology. Is this the case, though?

Isomorphic reasoning

In addition to ID's conceptual link between life and inventions, the isomorphic link between biology and technology also suggests that certain aspects of life will have specific conditions that are better studied

⁹ Alexei A. Erchak, Ripin, et al. 2001. "Enhanced coupling to vertical radiation using a two-dimensional photonic crystal in a semiconductor light-emitting diode." *Applied Physics Letters* 78:5. 29 Jan. 2001, pp. 563-565.

¹⁰ Pete Vukusic and Ian Hooper. 2005. "Directionally Controlled Fluorescence Emission in Butterflies." *Science* 310, 18 Nov. 2005, p. 1151.

¹¹ Kris M. Blair, et al. 2008. "A Molecular Clutch Disables Flagella in the *Bacillus subtilis* Biofilm." *Science* 320 (5883) 20 June 2008. p.1636.

¹² Erwin Schrödinger. 1944. *What Is Life? The Physical Aspect of the Living Cell*. Cambridge University Press, Cambridge.

If, instead, the problem had been treated as one of the chemistry of protein-RNA interactions, we might still be waiting for an answer.”¹⁵

Codes, which are used in human languages, were later found in nucleic acids. Proteins also have characteristics of a code. Codes are now readily recognized as a design isomorph, and also was the conceptual resource that guided the elucidation of DNA function. The isomorphic concept of informatic coding guided the illumination of the genetic material. The logic of symbols was and still is the *modus operandi* of molecular genetics and proteomics. ID’s conceptual link between technology and biology, by way of design isomorphs, holds very tight at the genetic level, from the beginning of its investigation to the present day.

The isomorphic relationships between biological parts and human inventions are more than analogies. Hubert Yockey explains how coding at the genetic level is more than a mere analogy and has a deeper meaning than simple anthropocentric equivocation:

“It is important to understand that we are not reasoning by analogy. The sequence hypothesis [that the exact order of symbols records the information] applies directly to the protein and the genetic text as well as to written language and therefore the treatment is mathematically identical.”¹⁶

The genetic codes are not codes in a loosely analogous way. There is an identity between linguistic codes and nucleic codes. Genetic sequences are codes in an isomorphic way.

Because of the known origin of codes and languages, this coding isomorph has direct implications for the origin of life. The only cause of codes and languages is intelligence. Any pathway to a code that lacks intelligent input needs to explain why the laws of physics and chemistry make a code inevitable under

specified conditions. Yet the very nature of codes entails contingency, not law-like rigidity.¹⁷ It is the message that specifies the required sequential order of encoding symbols, and a message implies an existing transmitter and receiver. The interdependence of coding among the parts of syntax, semantics, and processors of genetic information is a formidable chicken-egg-nest relationship between transmitter and sender on the one hand and encoding convention on the other, and so is also a fundamental example of irreducible complexity.¹⁸

Isomorphic reasoning has certainly helped the researchers studying the codes, algorithms, and ciphers of life. The isomorphic link between biology and technology at the genetic level is indeed clear, but what about other aspects of a living organism?

Reverse engineering

Another prime example of isomorphic reasoning used frequently in biological research is reverse engineering. Reverse engineering, long used by engineers to discover the inner-workings of a competitor’s complex machines, was and still is an incredibly effective conceptual tool for understanding the inner-workings of life.¹⁹ There are diverse methods of reverse engineering, including what is sometimes called “perturbation analysis.” This frequent application involves the removal of a part from a system in order to see how the removal of the part perturbs the system, and thereby disclosing a possible function of the removed part. The value of reverse engineering for biology should not be underestimated.

Reverse engineering has served biology at all levels of exploration and in many medical applications as well. Reverse engineering can help a molecular biologist discover the genetic basis of a protein or enzyme. Typical locations of a part of the cell can be investigated using reverse engineering. Metabolic pathways are reverse engineered in order to determine what biochemical components are involved. Developmental pathways for cellular components

¹⁵ John Maynard Smith. 2000. “The Concept of Information in Biology.” *Philosophy of Science* 177-194. June 2000, pp. 183-184.

¹⁶ Hubert P. Yockey, 1981. “Self Organization Origin of Life Scenarios and Information Theory.” *Journal of Theoretical Biology* 91:13, p. 16.

¹⁷ David Abel and Jack Trevors. 2004. “Chance and Necessity do not explain the origin of life.” *Cell Biology International*, Volume 28, Issue 11, pp. 729-739.

¹⁸ Michael Behe. 1996. *Darwin’s Black Box*. New York: Free Press. p.39.

¹⁹ Marie Csete and John Doyle. 2002. “Reverse Engineering of Biological Complexity.” *Science* 295, 1 March 2002, pp. 1664-1669.

like the bacterial flagellum are reverse engineered. Immune reactions are reverse engineered to determine which proteins serve what purpose in a cascade. Communication pathways like hormone channels are reverse engineered. Parts within tissues, organs, and organ systems are reverse engineered to help discover the roles involved. Functions at the highest organism levels are often ascertained by reverse engineering. Processes in ecosystems are reverse engineered to discern their relationships. If living systems could not be reverse engineered, our current knowledge of biological systems would be considerably less. In sum, biological investigations that are not resolved by direct observation are generally elucidated by way of the design-based methods of reverse engineering.

Strategic flight technologies

Flight technology revolutionized human warfare by adding an entirely new theater of battle in the skies. In the struggle for aeronautical supremacy, many strategies have been developed to provide an edge over competitors. The dawning of automated electronics made possible many complex technological strategies, known as electronic countermeasures (ECMs) and electronic counter-countermeasures (ECCMs). Parallel navigation, decoy signals, radar-jamming, stealth wing structures, meaconing, evasive maneuvers, and other strategies were born of the need for an edge in the sky wars.

Though these strategic flight technologies were new to our human technology, life had already actualized many of these flight tactics.²⁰ A long-standing struggle for supremacy in the air exists between the tiger moth and echolocating, predatory bats. As the strategic flight technologies of the moths and bats were scientifically explored and characterized, the human technologies that were isomorphic to the bat-moth stratagems served as conceptual resources to guide the scientific effort. It is possible that ECMs to be invented in the future are already in use by bats and their prey, but we do not yet have the conceptual or instrumental resources that would enable us to test

for the presence of these more advanced strategies in life.

Symbolic logic, reverse engineering, and strategic flight technologies were all human inventions that were subsequently found in nature, and the engineering uses aided in the exploration and description of the isomorphic biological systems. The isomorphic use of symbolic logic shows the effectiveness of isomorphic reasoning at the fundamental genetic level. Reverse engineering is isomorphically used at many levels of biological organization, including genetic, cellular, tissue, organ, organ system, and population echelons. Isomorphic reasoning about strategic flight technologies guides the exploration of an interspecies war in the skies. These three examples show the potent and wide-ranging effectiveness of isomorphic reasoning.

Isomorphic reasoning vs. Darwinian reasoning

The usefulness of isomorphic reasoning as juxtaposed with Darwinian reasoning offers insight into the history of bioscience. Two important figures in twentieth-century biology, Theodosius Dobzhansky and Francis Crick, offer us an interesting contradiction to ponder. On the one hand, Dobzhansky states that, "Nothing in biology makes sense except in the light of evolution."²¹ On the other, Crick states that science often makes sense of life without the "light of evolution":

"Biologists must constantly keep in mind that what they see was not designed, but rather evolved. It might be thought, therefore, that evolutionary arguments would play a large part in guiding biological research, but this is far from the case. It is difficult enough to study what is happening now. To figure out exactly what happened in evolution is even more difficult. Thus evolutionary achievements can be used as hints to suggest possible lines of research, but it is highly dangerous to trust them too much. It is all too easy to make mistaken inferences unless the

²⁰ Waters, D. and Jones, G. 2001. The Peripheral Auditory Characteristics of Noctuid Moths: Responses to the Search-Phase Echolocation calls of Bats. *The Journal of Experimental Biology*, vol. 199, issue 4, pp 847-856.

²¹ Theodosius Dobzhansky. 1964. "Biology, Molecular and Organismic." *American Zoologist*, vol. 4, p. 443.

process involved is already very well understood.”²²

What happened in the time between Dobzhansky’s statement in 1964 and Crick’s in 1990 that accounts for this dichotomy? One might suspect that what occurred in the interim was that biologists came to more fully understand biological processes, and at that point Crick was able to realize that Darwinism was mostly useless for this progress. Advancement of knowledge in experimental biology is driven mostly by observation, instrumentation and data collection. At the same time, hypothesis formation using theories like Darwinism are rarely helpful, and, as Crick explains, are often “highly dangerous” if trusted too much. National Academy of Sciences member Phillip Skell has also made significant note of this weakness of Darwinian thought in experimental biology.²³

Additionally corrupting in Darwinian thought is Charles Darwin’s use of theological reasoning to produce ideologically-charged explanations. Theological reasoning, about why or what a beneficent Creator would or would not do, pervades Darwin’s writings, especially *Origin of Species*.²⁴ Darwin’s heavy use of theological reasoning undermines an empirical approach to nature and sometimes even hinders the progress of bioscience. Nobel laureate Robert Laughlin explains the ideological problem we now face:

“Much of present-day biological knowledge is ideological. A key symptom of ideological thinking is the explanation that has no implications and cannot be tested. I call such logical dead ends antitheories because they have exactly the opposite effect of real theories: they stop thinking rather than stimulate it. Evolution by natural selection, for instance, which Charles Darwin originally conceived as a great theory, has lately come to function more as an antitheory, called upon to cover up embarrassing experimental shortcomings

and legitimize findings that are at best questionable and at worst not even wrong. Your protein defies the laws of mass action? Evolution did it! Your complicated mess of chemical reactions turns into a chicken? Evolution! The human brain works on logical principles no computer can emulate? Evolution is the cause!”²⁵

Darwinism in particular (and conceptions of unguided evolution in general) has not been very helpful to biology, whereas isomorphic reasoning has played a large part in guiding important biological research.

“More complex than once thought”

A revealing reason that Darwinian thought has not been helpful is that it tends to see biology in simplistic terms that are, well, too simple. When searching Google for phrases such as “more complex than previously thought,” over a million-and-a-half hits currently result. Some things that were “more complex than thought” from the first few pages include research findings in the following areas:

- communication among cells
- the oldest animal genomes
- bird flight orientation
- genes
- patterns of neuronal migration during cortical development
- the relationship between evolution and embryonic development
- p53 ubiquitination and degradation
- human memory
- the fetal immune system
- the mouse genome
- visual processing in the brain
- regulation of neuronal survival in the retina
- COX enzymes
- the human genome
- the female human body
- cerebellar circuitry and learned behaviors
- estrogen receptors
- neural induction

²² Francis Crick. 1990. *What Mad Pursuit: A Personal View of Scientific Discovery*. New York: Basic Books, p. 146.

²³ Phillip S. Skell. 2005. “Why Do We Invoke Darwin?” *The Scientist*, 19(16):10, August 2005.

²⁴ Cornelius G. Hunter. 2007. *Science’s Blind Spot: The unseen religion of scientific naturalism*. Brazo Press: Grand Rapids, MI, USA, p. 71.

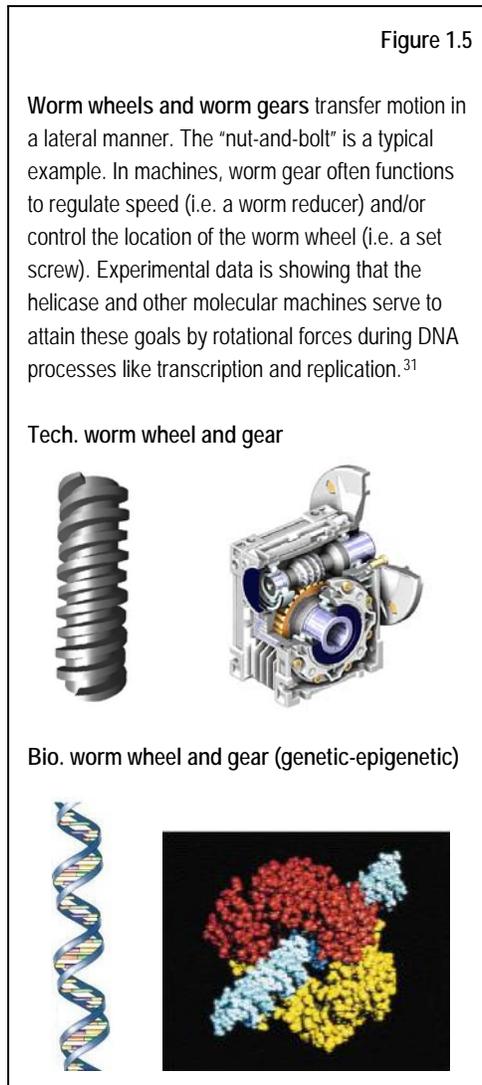
²⁵ Robert B. Laughlin. 2005. *A Different Universe: reinventing physics from the bottom down*. New York: Basic Books, pp. 168-169.

- the interaction between adipose tissue and the rest of the body
- the human transcriptome (RNA's)
- gene regulation by MEF2
- social lives of bats
- virus replication

According to current evolutionary views that see the unfolding of life as unguided, the apparent progress in evolution is a step-by-step gradual process. In these frameworks, life originated by blind processes, and it has since diversified and become more complex by other supposedly blind processes like neutral mutations, cooption, natural selection acting on random mutations, and other mechanisms working over vast eons. Though Eldridge and Gould's proposals from "punctuated equilibria" envisage rapid changes, even they admitted that genetic changes must somehow occur in a stepwise fashion, and an incremental building up of biological components is still present.²⁶ In other words, the increase was step-by-step, whether faster or slower increases in complexity, complexity always following simplicity.

But, on the contrary, we are learning that the beginnings of living systems were more complex than thought. The eukaryotic cell had high complexity from its known beginnings. As the list of things that are "more complex than thought" can show us, we actually see huge complexity near the beginning of major changes in life, with occasional losses among later categories of complexity. The chordate and mammalian "gene tool kits" are present from the be-

²⁶ Niles Eldredge and Stephen Jay Gould, 1972. "Punctuated equilibria: an alternative to phyletic gradualism." *Models in Paleobiology*. San Francisco: Freeman Cooper. pp. 82-115.



ginnings of the taxonomic level.²⁷ Contrary to evolutionary gradualist logic, what is being revealed from genome cataloging is that complexity appears early in evolution, especially at the cellular and sub-cellular level. The DNA code had its current maximal efficiency & operation (G,C,A,T) from its known beginnings to the present.²⁸ Current data indicates that there is limited common substrate space for kinases in eukaryotes, such that all eukaryotic kinases share one common set of chemical bases.²⁹

This proposed gradual evolutionary process is often conceived of as random mutations culled by natural selection, with mutations viewed as "tinkering" at the base pair level of the genetic material. Contrary to this view, it is thought that chromosome rearrangements play a greater role in the story of evolution, thus also making evolution more complex than mutation-based frameworks like neo-

Darwinism might lead us to think.³⁰

Known instances of true beneficial novelty by Darwinian evolution involve shuffling of existing parts or the degradation of parts. Reduction in function,

²⁷ Sean B. Carroll. 2005. *Endless Forms Most Beautiful: the new science of evo devo and the making of the animal kingdom*. New York: Norton.

²⁸ Freeland SJ, Hurst LD. 1998. "The genetic code is one in a million." *Journal of Molecular Evolution*. September vol. 47 num. 3: pp. 238-248.

²⁹ Sander H. Diks, Kaushal Parikh, et al. 2007. "Evidence for a Minimal Eukaryotic Phosphoproteome." *PLoS ONE* 2(8):e1777.

³⁰ Anton Crombach and Paulien Hogeweg. 2007. "Chromosome rearrangements and the evolution of genome structuring and adaptability." *Molecular Biology and Evolution* 24(5):1130-9, May 2007.

³¹ Ronald Laskey and Mark Madine. 2003. "A rotary pumping model for helicase function of MCM proteins at a distance from replication forks." *European Molecular Biology Organization (EMBO) Reports* 4:1, Jan. 2003, pp. 26-30.

complexity, or breakage of functional parts is often seen. One example of beneficial Darwinian evolution is antibiotic resistance. If attained by mutational change, this involves a reduction in function of cell membrane gateways, preventing the lethal antibiotic chemicals from entering the bacterial cell. These known cases of Darwinian novelty benefit through degradative change, not constructive alteration.³²

Isidore Rigoutsos, a lead scientist at IBM's Thomas J. Watson Research Center in Yorktown Heights, N.Y., is reported as saying that, “‘The picture that's emerging’ of how living cells actually operate and evolve ‘is so immensely more complicated than anyone imagined, it's almost depressing.’”³³ Nobel laureate Robert Laughlin gives one possible reason for this depression, “The Darwinian theory has become an all-purpose obstacle to thought rather than an enabler of scientific advance.”

Some of the “more complex than thought” mindset might be “media sensationalism,” but these statements often come from the researchers involved in the studies. One would hope that those involved with the research are being honest and truthful about their findings and the new data squares with the general view in their field of study. The fact that it is often the researchers that disclose their surprise lends support to the conclusion that this faulty gradualist mindset does actually exist, and could be impeding research progress.

Isomorphic reasoning would lead us to look at how one might engineer and design a complex device for a precise and intricate task. Engineers know that designing machines that fulfill complex, modulating, developmental, and protracted functions utilizing informational, algorithmic, and mechanical foundations is a monumental undertaking. A great deal of time, resources, effort, and/or intelligence must be applied to the task of instantiating complex machines. The functions of living organisms are much like this, and isomorphic reasoning is one way of thinking about life in order to more adequately anticipate the bio-

logical trend that life is “more complex than once thought.” Currently, “less complex than once thought” only returns two hits. The data coming out of the labs would suggest that we begin to expect that things are more complex. We would stand a greater chance of being correct.

Isomorphic reasoning would also put Einstein's Razor on a firm epistemic ground in biological reasoning. As a balancing factor to Occam's razor, Einstein's would be another ideal conceptual resource for addressing these mental “complexity roadblocks.”³⁴

Design isomorphs and the functional default

Another point where isomorphism offers a helpful path for biological reasoning is in the struggle between methodological views on how to approach biological function. Isomorphic reasoning offers guiding concepts that helps keep perspective on the goals of biological study. One way this is accomplished through isomorphic reasoning is by steering clear of what the biologist isn't doing. Isomorphic reasoning keeps in focus that the biologist isn't asking how something in nature serves no purpose or is functionless. The biologist cannot assume from the outset that something in nature will be meaningless, purposeless, disordered, functionless, or irrelevant. Science is focused on finding order, patterns, structure, and other quantifiable realities necessary to derive measurement and analysis. If the biologist begins with this non-functional default, this axiom becomes a science-stopping view, and isomorphic logic suggests this be generally avoided by a working biologist. Here is one evolutionary biologist reportedly using faulty, non-scientific reasoning of the non-functional type:

. . . T. Ryan Gregory, an assistant professor in biology at the University of Guelph, believes that nonfunctional should be the default assumption. “Function at the organism level is something that requires evidence,” he said.³⁵

³² Michael J. Behe. 2007. *The Edge of Evolution: the search for the limits of Darwinism*. New York: Free Press.

³³ Colin Nickerson. 2007. “DNA unraveled.” *Boston Globe*. September 24, 2007.

³⁴ Quinn Tyler Jackson. 2005. *On Einstein's Razor*. *Progress in Complexity, Information, and Design (PCID)* 4.2, November 2005.

³⁵ Catherine Shaffer. 2007. “One Scientist's Junk Is a Creationist's Treasure.” *Wired*, 13 June 2007.

Gregory might not be reifying a “non-functional default” into a practical axiom for biology in the way the reporter presents Gregory’s ideas, but analyzing such a reification is instructive.

Theoretically, one assumes that claiming functionality requires evidence, in the sense that we cannot claim a specific function until we have evidence of the specific function happening. But it is plainly stated at this juncture that a working scientist is trying to figure out the operations of nature. Biologists are trying to understand how life works. The goal of biology is to find the patterns, order, structures, and functions in life. They are not setting out from the start to figure out how the parts of organisms don’t work. Starting with the mental presumption that parts of an organism are non-functional brings no benefit to the investigator, and can be a severe cognitive impediment to research progress.

Should the default assumption be non-functional? How could one reliably know that any particular thing is non-functional? One would have to know a great deal about the physical attributes of the biological part, and its context, in order to make a determination that something is non-functional. In other words, only after the project of science is done, can an interpretation of non-functional be legitimately presented as an option. Therefore, the non-functional default is no help for the investigation of nature. In fact, the idea of a “non-functional default” is a promiscuous hindrance to science, since it would serve as a thought-

arresting dogma, not a useful axiom. The same applies for all “assumptions” of meaninglessness, purposelessness, disorder, functionless, or irrelevance. Non-functional is a possible conclusion, not a beginning point for science.

An example of this defeatist attitude was when many biologists brought a neo-Darwinian interpretation to

non-coding DNA and advised that the “junk” of the genome was assumed to be parasitical and didn’t have a useful purpose.³⁸ Isomorphic reasoning would suggest that even though some genes may appear to be non-functional or parasitical, this does not necessarily mean that we should assume they have no function. Instead, science should seek the order and function, and only after the investigation is finished can a conclusion of non-functional or meaninglessness be proposed.

Two goals bring strong confidence and motivation to the scientist; the twin objectives that nature has operations and that we can understand them. Without these two isomorphic and inherently teleological concepts, biology becomes illogical. Function at the organism level is the axiom of biological research, if for no other reason than we have so frequently found function after an extensive search, even when there was no discernable data that indicated function. A more productive approach is, “Part X probably has a function, so let’s explore the biomolecules and the surroundings to try and figure out its purpose.” In

this way, isomorphic and teleological reasoning can also serve as heuristics for biology (a heuristic being a concept that steers our effort towards an end that is more likely to be helpful). Not only is end-directed, teleological thinking an integral aspect of biological

Figure 1.6

Compasses are devices that utilize mineral magnetite affected by the earth’s magnetic polarity to specify relative geo-direction. Compass functionality can be found in magnetotactic bacteria that have an ability to “orientate and navigate along geomagnetic lines is due to intracellular magnetic particles.”^{36,37}

Tech. compasses



Bio. compasses (organismal system)



³⁶ Lins de Barros HG, Esquivel DM, Farina M. 1990. “Magnetotaxis.” *Science Progress*. 1990;74(295 Pt 3):347-59.

³⁷ Balkwill DL, Maratea D, Blakemore RP. 1980. “Ultrastructure of a Magnetotactic Spirillum.” *Journal of Bacteriology*, Vol. 141, No. 3, Mar. 1980, p. 1399-1408.

³⁸ Phillip Yam. 1995. “Talking Trash.” *Scientific American* 272, March 1995, p. 24.

reasoning, it is now clear that isomorphic reasoning has been critical to the history of biology.

Future uses of isomorphic reasoning

Presently unknown processes could be uncovered by using isomorphs to guide research. Further study of design isomorphs could accelerate research into the functions of DNA systems like repair regimes, error-detection mechanisms, and error-correction mechanisms.

Isomorphic integration in the interaction of biology and technology

Isomorphs suggest a deep connection between life sciences and engineering sciences. This deep connection has immediate implications for interdisciplinary fields that relate biology and technology. The means and efficiency by which biology and technology are interrelated in scientific practice is another revealing aspect of design isomorphism called *isomorphic integration*. There is a unique hand-in-glove fit between technology and biology. Many newer biological disciplines reveal an obvious practicality of the isomorphic perspective on types of research. Fields of research that operate on isomorphic integration have great promise and are emerging as possibly the most important and hardest impacting biosciences of the 21st century.

Consider biology and its relationship with many of the technological and applied sciences. Bioinformatics (especially genome, epigenome, proteome, transcriptome and other –ome cataloging projects), computational biology, systems biology, biotechnology, nanotechnology, biosemiotics, biomimetics, and cybernetics all show isomorphic interfaces that are being utilized by scientists studying living organisms.

In addition to being hauntingly similar to man-made teleological technology, biological components are compatible with computational analysis to a degree that was never expected by anyone, except perhaps someone who thought that biological organisms are the product of teleological intelligent design. Computational, programmatic, and technological analyses of biological realities produce a cornucopia of scientific possibilities. Establishing interfaces between biological components and human machines for computa-

tional analysis of organisms renders a technological methodology that is an apex of scientific tractability and productivity. Parts of the living cell can be analyzed via informational dimensions, technologically interfaced, mechanically understood, computationally quantized, electronically observed, predictably documented, rigorously calculated, reverse engineered, recognized, comprehended, understood, evaluated, theoretically explored, simulated, synthesized, emulated, and investigated with informational, algorithmic, and mechanical interfaces.

The cooperation among computational biologists, statisticians, mathematicians, computer scientists, engineers, and physicists shows that “systems biology” includes powerful methods for the scientific study of life. This systems-level view of life is a unique marriage of the biosciences with the engineering sciences, and its early successes are partially due to the fact that “approaches [to attaining system robustness] used in engineering systems are also found in biological systems.”³⁹ The systems biology approach reveals some of the higher levels of isomorphic integration.

Additionally, this investigative harmony between human inventions and organisms is unique among all other types of existing things that we know of. Because the DNA is isomorphically the same as a human language and computer codes, the same tools used to explore languages and codes are frequently applied to the DNA.⁴⁰ Computation reveals much about physics, chemistry, and other sciences. Yet, there is no such mirror between human technology and other phenomena quite like biology.

This veritable “plug-and-play” dynamic between biological phenomena and human computational machines is speaking profoundly to those carefully considering the evidence nature is presenting. In the mind of an ID theorist, this techno-scientific fitness is an exemplary reason to think that life was designed by intelligence. With such a profound similarity between biology and technology, is there any surprise

³⁹ Hiroaki Kitano. 2002. “Systems Biology: A Brief Overview.” *Science* 295, 1 March 2002, p. 1663.

⁴⁰ Phillip Yam. 1995. “Talking Trash.” *Scientific American* 272, March 1995, p. 24.

that some think that life was designed by intelligence?

Of particular note is the technological construction of artificial life including artificial genomes, artificial proteins, artificial cells, artificial organs, artificial intelligence, and directed proteomic evolution. All of these fields integrate, in a profound way, the technologies of the biotic realm with the technologies of the human realm.

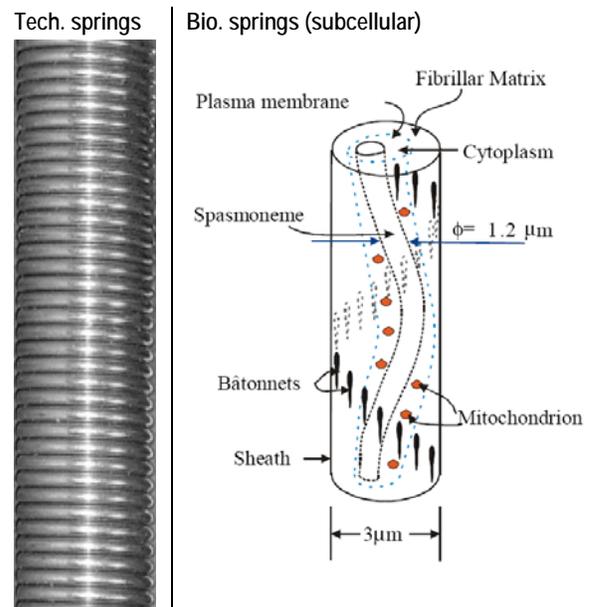
Biomimetics is also a very natural handshake to isomorphic reasoning, and it could be directly stated that biomimetics is reverse isomorphism. Often, living things have designs that are far superior to anything that has been technologically developed. In biomimetics, inventors and engineers seek out the complexity and efficiency of living systems for possible technological solutions. Since technological research is quickly becoming a vast array of microscopic and nanoscopic applications, fueled by a feverish rush to thrust more power into smaller and smaller spaces, the designs of nature are being increasingly relied upon for concept stimulation, as well as product research and development. From micro-batteries for artificial retinas, to nanotechnological carbon machines, looking to life for inspiration and guidance is quickly becoming an extremely important aspect of technological development.

Critics of ID are known to ask, "How would biological research be done differently if one thought that life was designed?" This, I think, is a misstated question. A better question would be, "How would one approach biological research if life was designed?" To answer this question, let us consider the jobs of a chemist, an engineer, and newer biology careers:

- Chemists studying interactions of matter and energy have in their toolkit the methods and approaches developed by previous chemists.
- Engineers studying functionally-directed systems have in their toolkit the methods and approaches developed by previous engineers.
- Systems biologists studying life have in their toolkit the methods and approaches developed by previous computer scientists and systems engineers.

Figure 1.7

Springs store and/or transfer mechanical energy by the bounding or rebounding of coils. Pond-dwelling protozoans called *Vorticella convallaria* have spasmonemes, which work as a retracting spring in response to environmental disturbances.⁴¹



- Biochemists, molecular biologists, and experimental biologists studying life have in their toolkits the reverse engineering methods and function-based approaches developed by previous inventors and engineers.
- Bioinformaticists studying life have in their toolkit the methods and approaches developed by previous inventors and theorists in information technology, telecommunications, and computer science.

The cutting edge of bioscience studies life as if it were designed by intelligence.

There are many other examples where isomorphic reasoning has brought great help to biology. These could be further discussed here, but the above examples of coding logic, reverse engineering, biological functionality, and isomorphic integration make clear the powerful utility of isomorphic reasoning. From

⁴¹ Yasushige Moriyama, Shigeo Hiyama, and Hiroshi Asai. 1998. "High-Speed Video Cinematographic Demonstration of Stalk and Zoid Contraction of *Vorticella convallaria*." *Biophysical Journal* 74, January 1998 pp. 487–491.

the beginning of the life sciences, to elucidation of the DNA code, to the study of many parts of an organism, isomorphic reasoning has led the way in some of the most important undertakings in biology. The conceptual resource of isomorphism stands next to the laws of physics, knowledge of chemistry, and observation, in terms of usefulness in biological exploration. And the future of isomorphism is shaping up to be brighter than its past.⁴²

Current isomorphic research: Isomorphic Evolution

In order for Dobzhansky's words about the "light of evolution" to ring truer, evolutionary biology may want to look more to isomorphic reasoning for inspiration, and consider what isomorphism means for the unfolding of evolution.

One example of *isomorphic research* applied to evolution currently underway is the work of Albert de Roos, who is using the software development concept of design-by-contract to propose evolutionary models of genome architecture.⁴³ With a design-by-contract approach, de Roos offers the idea that specific genetic elements (like intron splicing sites) could be interchange points upon which other genetic elements (like exons) are connected to, such that these introns would form stable interfaces that could allow modulation in other genetic elements. The work of de Roos is a direct application of isomorphic reasoning.

James A. Shapiro has discussed the possibility of "natural genetic engineering" in evolution.⁴⁴ His views on genome system architectures resonate in a profound harmony with design isomorphic reasoning.

Another example of isomorphic research into evolution comes from a recent bioinformatics conference, wherein the protein network in the living cell is topologically compared with the Internet.⁴⁵

From theoretical connection to plausible causal connection

Sometimes biologists use mental analogies between technology and biology to help them understand how life works. These analogies were originally developed as mental constructs to more easily wrap the mind around materials and processes in life. Analogies can make something complicated easier to comprehend. Biologists have had differing opinions about whether or not the analogies were really true. With design isomorphs, the analogies are, in fact, collapsing into reality.⁴⁶ Coordinated strategies and physical structures that have been intentionally developed for very specific purposes by intelligent inventors are being found to fulfill the same purposes in living organisms.

Discussing the possibility of intelligence as the cause of life is not a superfluous gloss, but has direct implications for how life should be studied. The existence, frequency, and foundational presence of design isomorphs suggest that there is a specific and profound link between biology and technology. Both biological designs and technological designs utilize fundamental aspects of the universe in order to manifest highly improbable boundary conditions that yield the distinct informatic structures, algorithmic functions, and mechanical units that constitute the respective biological and technological products. Isomorphic designs on the two distinct biological and technological levels both utilize the characteristics of space-time, fundamental forces, elementary constants, essential qualities of matter, and features of energy, so that

⁴² "The mechanical characterization of the cellular 'factory' is just beginning. Many more mechanical cellular functions are likely to be discovered in the future. This exciting new aspect of the inner workings of the cell challenges us to learn to think in terms of concepts heretofore alien to the trained biochemist." – Carlos Bustamante, et al. 2004. "Mechanical Processes in Biochemistry," *Annual Review of Biochemistry* 73, pp. 705–48.

⁴³ Albert D. G. de Roos. 2007. "Conserved intron positions in ancient protein modules." *Biology Direct* 2:7.

Albert D. G. de Roos. 2006. "The origin of the eukaryotic cell based on conservation of existing interfaces." *Artificial Life* 2006 Fall;12(4):513-23.

Albert D. G. de Roos. 2005. "Origins of introns based on the definition of exon modules and their conserved interfaces." *Bioinformatics* 21:2-9.

⁴⁴ James A. Shapiro. 1999. "Genome System Architecture and Natural Genetic Engineering in Evolution." *Annals of the New York Academy of Sciences* 870, 1999, pp 23-35.

⁴⁵ Q. Yang, G. Siganos, M. Faloutsos, S. Lonardi. 2006. "Evolution versus 'intelligent design': Comparing the topology of protein-protein interaction networks to the internet." *Computational Systems Bioinformatics Conference*, August, 2006. Vol. 5, p. 299-310.

⁴⁶ "With advances in physiology and the rise of modern biochemistry in the early twentieth century, the chemical factory or laboratory became the dominant metaphor for this biological unit. Today in the twenty-first century, the metaphorical imagery has become a reality, with cells acting as chemical factories for the synthesis of commercially valuable bio-products." – Andrew Reynolds. 2007. *Endeavour*. See previous footnote with same author.

they allow for similarly specified structures and functions. Humans must also choose among these same basic attributes of the physical universe to derive the same specified functions. These physico-chemical limitations also suggest that whatever non-human intelligence might have caused the informatic, algorithmic, and mechanical aspects of life, that cause has specific modes of operation that are isomorphic with human designers. The cause of life must have the ability to produce designs that can function within the same physical laws and conditions that human technology functions in.

What does the existence of isomorphs suggest about the cause of the biological side of an isomorph? Isomorphs cannot provide absolute proof that the biological side was caused by non-human design, since only the causal histories of the technological instances are known with strict certainty. One might acknowledge that the presence of isomorphs is highly suggestive of intelligent design. ID would predict that we should be able to find striking examples of similarities between biological organisms and technological inventions. This link resulting from ID premises is supported by the empirically verified similarities of design isomorphs, in which the likenesses between biology and technology are often mind-bending.

Extremely similar effects, similar cause

A simple exercise in retrodiction can allow one to explore the notion that isomorphs are suggestive of real design. ID suggests that both biology and technology are intelligently designed, resulting in a link between life and machines at a theoretical level. If technological products and biological products both have an intelligent cause, this conceptual link from ID premises suggests that we should find some type of conceptual, functional, or structural similarities among human inventions and the parts of living organisms. Why should we have reason to think that we should find these precise similarities, when we have no independently verifiable knowledge about non-human designers?

Are design isomorphs, isomorphic reasoning, and isomorphic integration some types of signs of intelligence? Some may think this is the case. In empirical science, verification can come from unexpected plac-

es. Though support can sometimes come from surprising directions, one is hard-pressed to imagine what stronger evidence for ID than isomorphism might look like. An encrypted video of an intelligent origin of life event stored on a disk of Martian substances discovered in pre-Cambrian rocks could be faked, and the lab notes of a non-human genetic engineer could be fabricated onto a carbon plate, and it is likely we could never know whether this evidence were real or not. Even if a non-terrestrial visitor appeared and showed us they had the capability of doing so, how could we be sure that they did cause life on Earth?

With design isomorphism, there is no fabrication or imagination, only real evidence from living organisms and working machines that implies that life was intelligently designed. If one is not open to the possibility that design isomorphism might be presenting signs of intelligence, it is likely an impossible task to open one's mind to the plausibility that intelligence is the cause of life. A rock-solid conviction against ID that does not think twice in the face of design isomorphs will probably never be challenged, and reliable empirical evidence that could shake such a strongly held anti-ID belief cannot plausibly exist. One cannot argue with a non-evidence-based construction of reality by an appeal to evidence, whether the evidence presented is design isomorphs or any other plausible set of data.

It is now a matter of observational fact that design isomorphs exist. Precise matches to things we know were intelligently designed are being found in life. What is the data and evidence that provide correlations sufficient to think it plausible that biology and technology were both designed by intelligence? One possible reason to infer intelligence is the sheer improbability that both technological and biological sides of a complete isomorph would have the same complex structures, utilize the same strategies, and fulfill the same purposes. But this makes ID an open scientific question, not a closed case.

ID is an empiricist movement within the natural sciences, reacting to the excesses of rationalism in Young-Earth Creationism (YEC), Old-Earth Creationism (OEC), and Darwinian evolution. YEC, OEC

and Darwinism have all been heavily influenced by rationalism, and much of it has been theological, all the while non-scriptural, heterodox, or unorthodox. The obvious examples of this are the “God wouldn't do it that way” premises that come from the three camps of YEC, OEC, and Darwinism.

A subtle part of the rationalism problem is the reality of unexamined alternatives. When one says that the answer to a particular question has to be A or B, then one is making the *a priori* assumption that A and B cover the entire range of possibilities. But how do we know there aren't other possible answers? This more subtle form of rationalism is common, and it often rears its head in scientific circles.

ID, on the other hand, minimizes the *a priori* axioms in order to bring greater focus on the scientific data. So ID does not mandate that this or that be true, but is limited to truth claims about the data and claims about how nature works.

Detachability

Despite the heavy ID overtones with design isomorphism, a great strength of isomorphic reasoning is its detachability from its theoretical causal chain. History has shown that isomorphic reasoning has been helpful whether one thinks the cause of life is intelligent or unintelligent. Without having stated that they are open to ID, Bruce Alberts,⁴⁷ Hiroaki Kitano,⁴⁸ Robert Eisenberg (citation in footnote 1), William Bialek,⁴⁹ and Scott Turner⁵⁰ have discussed the usefulness of isomorphic reasoning in biology.

Though design isomorphs provide evidence of the commonality between the cause of the origin of life and the cause of the origin of inventions, ID is de-

tachable from isomorphism. Indeed, an empirical search for signs of intelligence in nature is not dependent in any way on the existence or non-existence of design isomorphs.

Like any useful conceptual tool in science, there is no absolute commitment to the underlying mental reality. Because standard biological research is not committed to isomorphism by necessity, teleomentalism is still a very viable option for bioscientists when using isomorphic reasoning. Isomorphic integration and reasoning can be used as mental implements to understand nature, with the answer to the open question of intelligent design coming later through further study and exploration of nature.

From conceptual resource to metric-based resource

When considered together, a convergence can be perceived between the rapid development of biology and technology. Both the biological and technological worlds contain informatic and functional structures of vast complexity, diversity, and robustness. Bruce Alberts, former President of the National Academy of Sciences, stated that, “Given the ubiquity of protein machines in biology, we should be seriously attempting a comparative analysis of all of the known machines, with the aim of classifying them into types and deriving some general principles for future analyses. Some of the methodologies that have been derived by the engineers who analyze the machines of our common experience are likely to be relevant.”⁵¹ Alberts is correct about engineering being relevant to biological study, and the present work shows that this applicability is common. Design isomorphs can serve as fulcrums to guide this method of characterizing biology and technology as complex systems.

The next step for isomorphism is to develop a quantitative isomorphic rating based on measurements of the complexity and congruencies within functional, material, conceptual, and structural isomorphs.⁵²

⁴⁷ Bruce Alberts. 1998. “The Cell as a Collection of Protein Machines.” *Cell*, Vol. 92, 6 February 1998, pp. 291–294.

⁴⁸ Hiroaki Kitano. 2002. “Systems Biology: A Brief Overview.” *Science* 295, 1 March 2002, pp. 1662–1664.

⁴⁹ For example: William Bialek. 2001. Stability and noise in biochemical switches. *Advances in Neural Information Processing* 13, TK Leen, TG Dietterich & V Tresp, eds, pp. 103–109 (MIT Press, Cambridge, 2001). For more on Bialek's research, see: <http://www.princeton.edu/~wbialek/categories.html>. Accessed 18 Aug 2007.

⁵⁰ J. Scott Turner discusses Bernard machines as builders and agents of homeostasis in: J. Scott Turner. 2007. *The Tinkerer's Accomplice: how design emerges from life itself*. Cambridge, Mass: Harvard University Press.

⁵¹ Bruce Alberts. 1998. “The Cell as a Collection of Protein Machines.” *Cell*, 92, 6 February 1998, p. 291.

⁵² Jean-Luc Guillaume and Matthieu Latapy. 2006. “Complex network metrology.” *Complex Systems* 16, 1, pp. 83–94.

Matthieu Latapy and Clemence Magnien. 2006. *Measuring Fundamental Properties of Real-World Complex Networks*.

Chris Lucas. 2006. *Quantifying Complexity Theory*.

With such a metric, presented here as *Isomorphic Complexity* (abbreviated IsoC) the number of specific congruencies between the two sides of an isomorph would be enumerated and a rating rendered. Within such a metric, the number of isomorphic types involved could increase the rating by a specific factor, the number of specific congruencies would increase the rating by a specific factor, and the number of layered isomorphs would increase the rating. After this is accomplished, the scores would then be amenable mathematical analysis, and different types of comparisons and extrapolations would be possible.

Isomorphic Complexity Database (I.C.D.)

Quantifying isomorphic realities with IsoC ratings leads to the possibility of different types of research databases. One possibility is an Isomorphic Complexity database that would have two super-domains of data sets: one set for biological systems and one set for engineered systems (See Figure 1.8).

A common syntax and semantics for defining all aspects of currently known systems conceptual, structural, and functional dimensions would be established. A common syntax to characterize and quantify different systems would allow the two sets of biological and technological data to interface in the database. It should also be possible to form this quantification method such that new and undiscovered systems could be characterized.

Conventions for characterizing and quantifying complex systems are well developed, but interfacing available data from both technology and biology is still to be worked out. Methods for analysis of engineered systems have long been in place, and can be implemented through databases such as Unified Modeling Language (UML),⁵³ Infagon,⁵⁴ Object Role Modeling (ORM),⁵⁵ and Domain-Specific Languages (DSLs).⁵⁶

A framework for characterizing biological structures already exists in the Gene Ontology terms database⁵⁷ and Enzyme Commission number (EC number). Systems-level characterization and quantification of biological organisms is still developing, but has been significantly advanced by ground-breaking work in frameworks such as Systems Biology Markup Language (SBML),⁵⁸ Cell Markup Language (CellML),⁵⁹ and BioPAX.⁶⁰ Other frameworks could provide insights.⁶¹

Figure 1.8

Isomorphic Complexity Database (ICD)			
Tech isomorphs		Bio isomorphs	
◇	Structural	Structural	◇
◇	Conceptual	Conceptual	◇
◇	Functional	Functional	◇
◇	Material	Material	◇

A database of all technologies found both in life and in all inventions could bring greater knowledge to the relevant sciences. More types of heuristic guidance and new predictive abilities might also emerge.⁶² Newly revealed conceptual, structural, and functional dimensions of an unexplored biological component could be matched in the isomorph catalog with inventions having correlated technological characteristics, and thereby guide the biologist to technological counterparts that may serve to guide research. New methods of exploration and research could be developed. A database of this type could be a valuable resource

⁵³ See: <http://www.uml.org>.

⁵⁴ See: <http://www.infagon.com>.

⁵⁵ See: <http://www.orm.net>.

⁵⁶ Arie van Deursen, Paul Klint, & Joost Visser. 2000. "Domain-Specific Languages: an annotated bibliography." *ACM SIGPLAN Notices* 35.6. June 2000. ACM Press: New York, NY, USA. pp. 26-36.

⁵⁷ The Gene Ontology database has an excellent framework for standardized naming of biological parts, and could have valuable insights for an Isomorphic Complexity database. For an introduction, see www.geneontology.org/GO.doc.shtml. Accessed 18 Aug 2007.

⁵⁸ M. Hucka, A. Finney, et al. 2003. "The Systems Biology Markup Language (SBML)." *Bioinformatics* 2003, 19(4): pp. 524-531. See also <http://www.sbml.org>.

⁵⁹ See: <http://www.cellml.org>.

⁶⁰ See: <http://www.biopax.org>.

⁶¹ MathML, SGF (Structured Graph Format), Chemical Markup Language (ChemML), MoDL (Molecular Dynamics Language).

⁶² Hiroaki Kitano. 2002. "Systems Biology: A Brief Overview." *Science* 295, 1 March 2002, p. 1663.

to researchers in molecular biology, biochemistry, genetics, epigenetics, systems biology, biotechnology, biomimetics, and others studying complex organic systems.

Meta-Isomorph Database (M.I.D.)

Another possible isomorphic database is one that could render an interdisciplinary analysis of major trends in 6 subsets of data: the 2 sides of design isomorphs, biological evolution and convergences in life, and technological evolution (TRIZ)⁶³ and convergences in technology. (See Figure 1.9) If these sets were all subjected to comparative analysis, this database could reveal new knowledge about the worlds of technology and biology that could hold the key to new knowledge about complex systems, and possibly some very important evolutionary predictions.

Feasibility

Biologists, biophysicists, computational biologists, computer scientists, and inventors have been briefed on ideas presented in this paper. Their opinion is that, based on our current rate of scientific progress, these types of isomorphic databases may be many decades or several centuries away. However, this effort cannot be dismissed since the finding of characteristic similarities and convergence patterns between biological evolution and technological evolution may reap unimaginable benefits for the life sciences, and also in technological applications of scientific knowledge.

Isomorphism and the future

Through ideas presented in this essay a design-based perspective of biological research can be perceived, and could be generally labeled “design isomorphism.” The design isomorph, isomorphic reasoning, isomorphic integration, and Isomorphic Complexity all show a rich outgrowth of design-based views in biology, and even offers a “total package” perspective for a biologist. That is to say, design isomorphism is an approach that offers an overarching view

of most theoretical and practical dimensions of biological practice.

Figure 1.9

Meta-Isomorph Database (MID)			
	Bio isomorphs	Bio evolution	Bio convergences
Tech isomorphs	▽	▽	▽
Tech evolution	▽	▽	▽
Tech convergences	▽	▽	▽

Design isomorphism also presents many future opportunities for further discussion of scientific connections between technology and biology, especially in biomimetics, complex systems theory, organizational theory, theories of innovation, TRIZ, and nanotechnology. History and philosophy of science topics also issue from this framework, including causal and inductive implications. Ontological and ethical considerations about life and its relation to human technological progress also spring from design isomorphism.

One might be surprised that all of the “simple machines” are found in living organisms. In addition to the worm gears and screws already mentioned (DNA double helix and helicase), there are also inclined planes and wedges,⁶⁴ levers,⁶⁵ pulleys,⁶⁶ and wheels & axles.⁶⁷ These and other facts have Platonic undertones that merit philosophical consideration.

⁶³ Genrich Altshuller. 1999. *Innovation Algorithm: TRIZ, systematic innovation and technical creativity*. Technical Innovation Center. 1st edition, 1 March 1999. – Semyon D. Savransky. 2000. *Engineering of Creativity: Introduction to Triz Methodology of Inventive Problem Solving*. CRC Press.

⁶⁴ An animal claw is a wedge device. Wedges and inclined planes are essentially the same device type.

⁶⁵ Joints such as the elbow and knee serve as levers.

⁶⁶ Ardeshir Bayat, et al. 2002. “The Pulley System of the Thumb: Anatomic and Biomechanical Study.” *Journal of Hand Surgery* 27A:4, July 2002, pp. 628-635.

⁶⁷ The ATPase and the bacterial flagellum both utilize wheel & axle structures, and the tumbleweed also utilizes a wheel-based function.

Given the ubiquity and strong likenesses between isomorphs, the fact that the birth of the life sciences was marked with isomorphic reasoning, and since isomorphic reasoning has been incredibly helpful to biological practice up to this day, the causal link between products of human intelligence and the possible intelligent cause of life is strengthened. As such, design isomorphs are not literally “vindications” of ID. Instead, isomorphism is 1) a clear example of how ID-based reasoning has profoundly helped research biologists, 2) a conceptual resource that says that ID-based reasoning will continue to be helpful to researchers, 3) a framework that provides powerful heuristic guidance, 4) has a strong potential of being developed into a conceptual resource that can yield precise predictions, and 5) a reason to think that intelligent design will one day be more fully-affirmed by the evidence.

The veracity of Eisenberg’s advice referred to at the beginning of this work should now be abundantly clear. The further into the living world scientists penetrate, the more we find design isomorphs to be present. The more we learn about biology, the more isomorphic integration and isomorphic reasoning is needed to understand and utilize the data. Will this trend cease? Given the track record of isomorphism in biology, a slower tempo is not expected. Since the deeper we look into biology the truer it is that life is “more complex than once thought,” the isomorphic trends in bioscience can certainly be expected to continue gaining momentum.