Legitimacy and Scope of "Naturalism" in Science

Part II: Scope for New Scientific Paradigms

Part I presented a theological basis for naturalism in science. As an intentionally limited discourse, science is sustained in a subsidiary context of religious/philosophical beliefs, whose adequacy and scope affects its creative horizons. I argue that biological systems cannot be adequately understood in terms of the materialist, mechanist, and reductionist assumptions appropriate to physical science, but require broader naturalistic explanatory paradigms. An organizational logic concerned with certain types of function or achievement is manifest in biological organisms, which is distinct from the principles of physics. Examples are given showing how tacit use of this logic influences current biological research.

> *[The paradigm for science found in Genesis 2] provides no basis for the idolatrous claim to unlimited dominion and power based on reason, which is at the heart of modern secularism.*

Part I gave important theological reasons for scientific naturalism:[1] it is a methodological policy limiting the scope of science, understanding that God is transcendent with respect to creation. We do not find a biblical paradigm for science and human rational creativity in the *imago Dei* of Genesis 1, but in the creaturely context of Genesis 2—the story of Adam naming the creatures. Reason is a creaturely gift, related to our vocation to cultivate and keep creation as stewards accountable to God. In naming creation, we should use *creaturely terms of reference*, recognizing that we cannot name God himself by our own rational powers. God and his mysterious agency in creation are not subject to mundane scrutiny; knowledge of God depends entirely on God's sovereign and gracious choice to be known personally—as the Scriptures consistently teach.

Such "naturalism" is not, therefore, a methodological atheism which excludes God from his creation. Recognizing the legitimacy of our rational powers within creation, it identifies their limits. Finding the paradigm for science in Genesis 2 also reminds us that, from the divine point of view, true authority is shown in *servanthood*. It provides no basis for the idolatrous claim to unlimited dominion and power based on reason, which is at the heart of modern secularism.

Theological grounds for "naturalism" insist on a clear distinction between a naturalistic scientific discourse and a much richer, contextual framework of religious/philosophical belief necessary to sustain it. But in contemporary secular culture, the naturalistic paradigm of a mechanistic, purely material world *also* has been adopted as an exclusive religious and philosophical belief system, i.e., as the contextual framework sustaining and informing science. Christian critiques of such *philosophical* naturalism correctly argue it is inappropriate and inadequate for that task.

However, arguments for or against naturalism will remain mostly academic unless there are potential consequences for science itself. I argue here that "naturalism" as defined in Part I has a much greater *scientific scope* than the *status quo* meaning allows, *for biology in particular*. Extreme Darwinism's claim that life can be explained by natural selection, random mutations, and lots of time is not really based on scientifically convincing evidence. It is based on *a priori* belief in a closed metaphysical view of "nature" that is materialist, mechanist and reductionist—belief having the status of religious dogma, as "the scientific world view."

Of course this view is the naturalistic paradigm of the world physics describes, and its severely limited scope *is* appropriate for that purpose. It is significant that most Christian critiques of naturalism in science tacitly agree on its adequacy for physical science. For that particular enterprise, *it is not broken, and does not need fixing*.

Is there something which *is* broken, and which therefore needs fixing, in current scientific thinking about biology or biological origins? Christian critiques of Darwinism, which advocate the idea of "intelligent design" as a scientific approach to biological origins, certainly argue that this is the case.[2] However, these critiques also reject "naturalism" in science, since they argue that a specific external agency is scientifically detectable in the design and function of living things.

The argument presented here agrees with these critiques that something is lacking in current thinking about biology; but it differs strongly from them by maintaining that this does *not* mean we should introduce an "intelligent agent" as a scientific surrogate for divine agency in creation. Instead, we need a new "naturalistic" biological science which is more than the application of physical science to biosystems.

Biology and the Presuppositions of Science

Historically, a *mechanistic* definition of "naturalism" was heuristic, not essential.

Robert Boyle's adoption of naturalism in science was motivated by theological concerns like those argued in Part I. He wished to mark off a limited discourse about nature in creaturely, internal terms of reference, distinguishing it from broader discourses which necessarily have theological reference. This theological and philosophical move is the most important element in Boyle's approach to science.[3] The particular presuppositions of *mechanism*, *reductionism,* and *determinate causation* peculiar to the "mechanical philosophy" were a secondary choice, *heuristically* adopted for the specific enterprise of physical science. Their adequacy as a paradigm for physics has been demonstrated by its success over more than three hundred years. In assessing this history, we should admire Boyle for his boldness and astute judgment concerning the open possibilities in physical science, not fault him as the father of a methodological atheism. Criticizing the mechanistic paradigm because it was later made a basis for atheistic belief really misses the point.[4]

A second look at Boyle's approach can give us useful new insight. Using the clock as an example of both design and mechanistic behavior, Boyle specifically illustrated the idea of a discourse with terms of reference limited to certain kinds of meanings. He also tried in this way to identify subject matters lying within or beyond such terms of reference. "Mechanical philosophy" formed the germ of what we call physical science. The notion of the machine as an embodiment of natural laws and causal, determinate connections has been very relevant to the history of modern science; we shall argue that it has still more to offer from a second, rather different viewpoint.

Boyle believed that adequate explanation for the behavior and development of living things lay beyond the scope of scientific discourse—an opinion mostly shared by his contemporaries. Scientists of Boyle's day recognized that mechanical descriptions are relevant to biological systems—consider, for example, Harvey's work on blood circulation—but a mechanical account was seen as peripheral to *proper* explanations of their form and behavior, which remained essentially teleological (and therefore also *theological*).[5] Terms of reference established for the Boyle Lectures (to the Royal Society) proposed that lecturers show evidences from their work for a divine design in nature; Boyle's belief that biological organisms could not be explained by purely mechanistic theory certainly had some bearing on this, and also on the eighteenth century flowering of a scientifically unfruitful "natural theology," which tried to *explain* biological systems as examples of divine purpose and design.[6]

However, the conclusion that biology could not be a fully "naturalistic" science did not derive from Boyle's primary idea of science as a discourse limited by creaturely terms of reference. *It resulted from the secondary, heuristic identification of such limits with the working terms of reference established specifically for physical science.* While these have proved remarkably durable and fruitful, we should not assume they define the character of all scientific explanation for an indefinite future. "Naturalism" able to sustain a true *bio-logical* science may require broader paradigms of scientific meaning.

Is the account of biology given by physical science an adequate explanation?

The success of physical science has blinded us to what it does not and cannot comprehend within its explanatory paradigms. In scientific thinking, we easily miss the distinction between the idea of mechanism in the context of a functional system in which it plays some role, and the reductionist idea that mechanism gives a *fully adequate account* of that system. The question of adequacy does not arise if we seek only to describe the mechanistic structure itself, without also seeking rationalization for the entire system's existence and complex organization. Such a

purely mechanistic study of biological systems has necessarily been the initial task of modern biology; studying the physics and chemistry of living things is a first step toward true understanding.

However, *the question*, whether a purely mechanistic description offers an adequate explanation for living things, *also cannot arise if we decide in advance to legislate it out of existence*. Just such legislative decision is hidden in tacit, reductionist assumptions that mechanical structure and physical laws are necessarily sufficient to account for the form and function appearing in biosystems. Such assumptions are central to extreme Darwinism.

The laws of physics appear to provide a valid, coherent structural and mechanical account of the world—*including* biological systems. I do not think that we lack some unknown but essential principle of physics needed to account for the physical and chemical processes occurring in biosystems, or that the study of biological behavior will turn up mysterious violations of currently understood physical principles. Fifty years of molecular biology/biophysics provide convincing evidence to the contrary: Biological systems do behave according to the mechanistic laws of physics. Within the limits of measurement, and conceptual limits to what "complete specification of the state of a physical system" means (and also leaving aside such matters as whether quantum uncertainty or chaotic dynamic instability play key roles in brain behavior, for instance), a purely physical description of biosystems is comprehensive within its terms of reference, showing no hint of mysterious "gaps." The mechanical account *works*, and we even know the physical/chemical structure of the human body in increasing detail, down to the molecular level. In some cases, as the human genome project is showing, we can even link disease or dysfunction to variant molecular species and events they cause.

But does a purely mechanistic description really explain what is essential to biology: namely, its complex functional entities and their unique behavior? I suggest that it does not, and that current research supports this conclusion.

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Michael Polanyi, the open presuppositions of science, and the question of a distinct "bio-logic"

The idea of a "bio-logical" science distinct from the *physical science of biological systems* challenges the entrenched materialist, reductionist, and mechanist legislative assumptions I referred to earlier—which define science *a priori* as physical science. It forces us to ask the *epistemological* question, "Can we define explicitly what the presuppositions of science are?" In *Personal Knowledge*, his major work on the philosophy and epistemology of science, Michael Polanyi argued that the presuppositions of science cannot be fully specified.[7] The operating assumptions which motivate current scientific inquiry, shape its legitimate subject matter and explanatory paradigms, and establish its specific methodology cannot be fully stated in advance of the enterprise itself. They are always partially tacit subsidiaries to it. Only after the achievements of a new science become manifest can we begin to make the underlying presuppositions supporting it more explicit. Polanyi argues further that whenever scientific enterprise is active, an inarticulate, tacit component necessarily remains in our participation as personal knowers.

Attempts to fit radical new discoveries into the presuppositional framework of already existing science may produce incongruity and a sense of its inadequacy, the more so as the issues in question demand major changes in thinking. At crucial points in the enterprise, inadequacy of an older integrating framework becomes evident, and the future depends on a more open approach to tacit or unquestioned presuppositions. Just at such moments, Polanyi argued, the personal, tacit component in our power of knowing is most essential to creativity, and the formalized elements of method and analysis offer us least help in "breaking out" of an old framework and "indwelling" a new one. Some of the "scientific revolutions" to which Kuhn[8] and later others have drawn so much attention are not just "paradigm shifts" at the mundane level of theoretical models, but constitute profound changes in our entire perception of what may constitute legitimate *scientific meaning*.[9]

What makes biological systems distinctive (and transcends purely physical description) is that they embody, at every level—from a whole organism down to the molecular structure of a cell and its constituent parts and processes—a logic controlling achievement of certain tasks or *functions*. This abstract logic (rather than the causal logic of physical mechanisms) is what *explains* the particular organizations of physical/chemical structure present. This is not just philosophical speculation, but is suggested by biological research itself as complex details of molecular structure and mechanism in biosystems become better known.

In *The Chief Abstractions of Biology*, the late Walter M. Elsasser argued for such a view on purely scientific grounds.[10] A physicist by experience and critical viewpoint, Elsasser realized that the phenomena of greatest importance for biology arise from highly coordinated functions of structurally complex systems. He argued that the main conceptions of physics are not appropriate to describe these phenomena, although the detailed behavior fully obeys physical principles. Physics deals with relations which are determinate and causal in great detail, for which mathematics provides apt descriptive tools and language (e.g., in the differential equation). But such a theory is not effective for the problems of central interest to biology, such as *morphogenesis* (development of biological form in an organism). Illustrating this thesis, Elsasser pointed out, for example, that there is enormous variation in all the chemical and physical parameters characterizing a particular organ or body feature over the individuals of a species, often 30%–40% or even a factor of 2 or 3 in some cases. Yet nearly all these individuals are fully *functional* representatives of their species. Such variation in physical/chemical parameters is, of course, essential if biological life is to be even minimally adapted to variable environmental resources and constraints; but it powerfully suggests that the logic governing exploitation of these resources for an individual organism's development is organized toward the overall performance of the organ or body function as an outcome or achievement. The challenge for our thinking about such problems is indicated, Elsasser said, by the fact that the part of biological function we understand best is just *the part most like physics*, i.e., the exact replication processes operating in genetic material; morphogenesis by comparison is a much more formidable problem to characterize logically.

This observation remains true today. With the development of chaos theory and better understanding of higher-order pattern formation in complex dynamical systems, we can account for some aspects of growth and development and give plausible mechanical explanation for some elementary developmental principles; but we still have no understanding of the organizing logic, which uses these mechanisms in a clearly programmatic way. While Elsasser was not able to push his discussion through to synthetic construction of a "bio-logic," he presented arguments supporting the idea. In particular, he argued that (a) biological systems obey rules and constraints which are logical and coherent, but are not derivable from physical laws, even while fully compatible with them; (b) the relevance of mathematics for formulating these rules is problematic, since the processes they regulate are not rigorously determinate at a macroscopic level; (c) no adequate grounds exist for using statistical principles to deduce or explain such logical organizations as "most probable," because the number of individuals of any single species which have ever existed over geologic time is fantastically smaller than is required for a statistically significant sampling of the available parameter space spanned by *observed* individual variations.

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Some evolutionary biologists, notably S. J. Gould, propose that the specific history of living things is highly idiosyncratic (as Elsasser also emphasized), and argue that the complex functions they have developed over time are peculiar to the particular path which evolutionary development took. This would imply that Elsasser's logical "rules" are perhaps "learned" and handed down from the past as a vital part of biological inheritance, along with the particular structural entities which embody them. This is a plausible thesis, to be considered on its own merits. However, it neither explains such a logic as the *result* of mechanism, nor invalidates the claim that it is *objectively real*. We should take the existence of these "rules" seriously, and learn their logical organization, before we assume too much *a priori* about their origins. As Elsasser proposed, this can best be done by examining biosystems from a different, logically disjoint standpoint. We should not obstruct that task by *a priori* legislation of materialist strictures against the hypothesis that such a logic could be *objectively real*, just as the physical order is real. This offers a genuinely *scientific* response to the judgment of many people today that a purely mechanistic theory of biological evolution cannot explain what we see.

Dialogue: Article

Legitimacy and Scope of "Naturalism" in Science
Part II: Scope for New Scientific Paradigm

In the rest of this essay, I present further argument to clarify the idea of function vs. mechanical structure as logically distinct ways of looking at a system, and illustrate ways in which the idea has tacit influence on scientific practice.

Biosystems and the Logic of Function

What is the *logical* status of the idea of a genetic "code"?

Let's consider that topic of biology most congenial to physics: the genetic replication system. In the four to five decades since the structures of DNA/RNA and their mechanistic relations were worked out, accounts of their meaning for biology, at both lay and professional levels, invariably make them *intelligible* by *analogy with the role of code in a digital computer*. Such "explanation" is now so familiar that it is tacitly accepted as legitimate without anyone raising an eyebrow. But this analogy does not refer to the physical structures and mechanisms in the two kinds of systems, biosystem and computer. It refers to the *function* of sequenced code in controlling complex operations, i.e., to the logical meaning of the computer as a Turing machine.

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Attempts to point out this distinction often meet with immense suspicion. The magic of reductionism, the belief that physical structure and mechanism must somehow be able to account also for complex function, is so strong that people work and live every day with such tacit "explanations" and never recognize their philosophical importance. While many people recognize a problem posed by the "information" encoded in DNA/RNA, the hypothesis that it may be intelligible or explainable only in terms of a logic disjoint from that of physics is not readily considered or accepted. Perhaps one reason for this odd state of affairs is that everyone knows that the digital computer, the entity whose analogous functional performance makes DNA/RNA intelligible to us as biologically significant, happens to be an artifact of human design. That fact raises philosophical and religious questions more disturbing to some people than the strange surprises of modern cosmology.

Here a disclaimer is necessary! *I am not trying to argue in any way for "intelligent design" as a scientific hypothesis.* I do not wish to draw that particular parallel from the DNA/RNA-digital computer analogy. I have a much more limited point to make.

In understanding a digital computer, we recognize that there are two distinct and logically disjoint ways of looking at it. One description is most relevant to the electrical engineer; it looks explicitly at the computer as a particularly organized bundle of physical connections and the mechanisms those connections set up (to do whatever a computer does). A logically complete and internally coherent account of the computer as a purely physical entity certainly exists. But there is another, logically disjoint account of the computer, equally complete and coherent; this account describes it as an entity accomplishing certain kinds of tasks or functions called *computation,* and subsumed under the abstract concept of the Turing machine.

To say that this second account of the computer is nothing more than the first one dressed up in a different language, or to claim that in the long run the first description sufficiently explains the computer, would be both absurd and operationally useless. We accept the fact that the logic of computation embodied in a particular digital computer is real and coherent in itself; quite different embodiments of the same logic may exist, whose physical structure and mechanisms are fundamentally different from those now in use. Further, we also recognize that the second account of the computer has a certain logical priority in relation to the first one. Such mundane acceptance of the reality and utility of a disjoint logic, a logic concerned with a different level of meaning and different questions and answers than physics deals with, is all I am after from a *scientific* viewpoint. The fact that we did not create the genetic replication system, but discovered its objective existence and then found its "explanation" in analogy to the computer, may raise legitimate *nonscientific* questions; *but they are not the concern of this essay.*

The logically dual nature of a machine offers a useful introductory paradigm.

Historically, the picture of nature as a machine formed the initial paradigm for the rise of a mechanistic physical science. It gave Boyle a powerful heuristic way of distinguishing the immediate, limited aims of physics from the broader concerns of theology; it encouraged the "disgodding of nature", i.e., the rejection of the pagan idea of nature as divine, replacing it with the biblical doctrine of the transcendent *monarchia* or sovereignty of God over creation. Reconsidering the idea of the machine as a paradigm of nature can offer us now a further point of departure for innovative *scientific* thinking which is both philosophically reasonable and maximally consistent with our historical scientific past. It also preserves the theological emphasis on a transcendent divine sovereignty so important to Boyle.

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Michael Polanyi introduced the idea of a disjoint logic embodied in biosystems by taking just such a second look at the concept of a machine.[11] To know some entity as a *machine*, Polanyi said, we must understand not only the physical principles on which it relies, but must also have a conception of the achievement it embodies: those *rules of proper function* which really govern what it is and does. Without a knowledge of these rules and their coherent logical relationships, one can neither understand a thing *as* a machine, nor fix it if it is broken. The indispensable character of this knowledge, and its logical independence of physics, can be shown by two simple observations: (1) A broken machine which no longer functions correctly obeys physical laws as fully as one in perfect working order; and (2) To any person who knows nothing of this disjoint logic of function, the machine—broken or not—is merely a strange and meaningless set of physical connections. Everyone realizes the truth of these commonsense principles when trying to understand (or repair) a strange or very complicated machine for the first time.

In the case of machines we have built, a kind of isomorphism normally exists (for reasons of economy) between the logic of function governing the machine's proper working and the set of physical mechanisms this logic uses in its operation. Thus we often overlook the important logical distinction between the two levels of understanding: machine structure and machine function are tacitly merged in our thinking. But the distinction immediately becomes relevant if we entertain the hypothesis that some entity *we did not make* is in fact a machine, or appears to behave like a machine, *because it achieves logically coherent tasks or functions*. In that case, our tacit faculties of judgment must be called into play, and we begin to look at the entity, not merely as a meaningless jumble of physical mechanisms and components, but in terms of some imaginative, synthetic reconstruction of the task or tasks it accomplishes—that is, what its *function* is. *Precisely this kind of synthetic thinking is critically important to research in molecular biology today.*

The logic of function and Behe's idea of irreducible complexity

Substantial scientific meat has been put on these philosophical bones in some clear examples of such logical organization in biological systems presented by molecular biochemist Michael Behe in *Darwin's Black Box.*[12] Behe begins by remarking that while the use of limited teleological explanations for organism structure and function always formed a part of biological understanding, this was always excused by claiming that the need for such explanatory paradigms would disappear when we finally analyzed biosystems at a microscopic, molecular level. There, the reductionist creed asserted, the sufficiency of simple mechanism to account for the complex and apparently coherent behavior of the whole would become obvious. But this is *not* what has happened. Instead, in detailed microscopic structure within a single cell, one finds *molecular machines,* assemblies of extraordinarily complex mechanical units which together function coherently and, in a logically unique, usually time-sequenced fashion, perform specific tasks such as the synthesis of particular enzymes/proteins. Still higher level organizations of molecular structures to form mechanical devices with obvious function, such as the bacterial *flagellum*, also exemplify Polanyi's idea of the machine as a logically dual entity, described both by a logic of achievement and by the physical principles this logic employs.

Behe challenges the claim that such systems can be explained as the result of infinitesimal modifications of simpler precursors by random microscopic mutations, reinforced at each step by natural selection. He describes them as *irreducibly complex*, i.e., "composed of several, well-matched interacting parts that contribute to the basic function, wherein the removal of any one of the parts

causes the entire system to effectively cease functioning." Such a system *has* no discernible simpler precursors; no simpler fragments of it achieve anything whatever.

I agree with Behe that the existence of such systems is a strong argument against the myth of the blind watchmaker.[13] However, I want to make a quite different point, which I think is even more obvious.

The notion of the achievement or function performed by an "irreducibly complex" system, and the logical rules governing the assembly of physical mechanisms which perform that function, are essential to scientific understanding of what the system is and means. The idea of an irreducibly complex system tacitly implies that such a system's function is logically simple or unitary, while the particular assembly of physical components achieving that "minimal function" has an otherwise inexplicable complexity. Understanding such systems necessarily involves thinking about how they are organized toward the functions they achieve, quite apart from any hypotheses about their emergence or origins. Therefore, scientifically meaningful accounts of biological systems can and should be given in terms of their logical organization toward function or achievement. This logic is what explains and determines their complex physical structure.

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To insist that such logic is only "apparent," that it has no objective reality independent of our minds, or that it is merely a by-product or epiphenomenon of the physical processes themselves, is an obstructive and sterile argument whose only basis is dogmatic belief in materialism. Yet just such an arbitrary, dogmatic and a priori legislation in favor of a materialist, mechanist and reductionist account of biology, rejecting any other view, is the program of extreme Darwinism. Those who argue that other accounts are "purely subjective" should remember that before the rise of physical science, equally plausible claims could have been made that the concept of *physical* laws is "subjective." Confidence in their objective reality results from the manifest knowledge of nature which responsible commitment to them has produced since the seventeenth century.

While Behe's book describes only a few examples of irreducibly complex systems, such systems are not rare, but a characteristic feature of biological organisms.[14] Behe concludes that the universal appearance of such "molecular machines" in living things is evidence for "intelligent design." While this is a legitimate *theological* reflection, I do not think the idea of "intelligent design" helps us with the *scientific* problem posed by biological systems; Behe's idea of "irreducible complexity" does.[15]

Function **is crucial, not mere complexity.**

The idea of "irreducible complexity" has scientific merit because it depends crucially on the concept of an achievement or "defining function" accomplished by such "molecular machines." Complexity itself, or the potential merit of non-reductionist accounts of complex dynamics, are not the real issue. Many people agree that functioning biological systems are instances of extremely complex physical dynamics and that the most fruitful descriptions of such systems are non-reductionist; but they would still argue that the functions achieved are incidental to scientific understanding. This misses the point.

Many natural physical systems of great complexity exist, which are *not* machines because they accomplish no logically comprehensible task. The ring systems of the outer planets and other extraordinarily intricate dynamical systems which astrophysics has explored are examples; so are structures such as Benard convection cells in a heated fluid, flame pattern dynamical structures, and many other forms of self-ordering behavior in nature. Perhaps the *weather* is the paradigm example of a complex, highly organized kind of behavior exhibiting recognizable patterns of order, and having a definite, coherent relation to certain kinds of events; but it is behavior which certainly does not have any discernible function or achievement in the sense understood here. What defines a *machine* is the existence of a coherent logic specifying a particular kind of achievement; and I am arguing, as Polanyi did and Behe demonstrates, that biological systems clearly manifest such an internal logic. The fact that leaf contours or branching of trees follow rules described in non-reductionist models of mechanical behavior is interesting; it shows we still have much to learn about the multiplicity of physical levels at which biosystems function. But it has no direct bearing on the idea of a distinct logic of function.

The frequently emphasized distinction between the notions of *order* and *information* is also relevant here. It has been suggested that somehow "information" is merely highly complex order, and that (presumably) some inherent physical stability in this order explains its emergence. Attempts to explain the information in DNA/RNA by comparing it (for example) to the kinds of self-replicating long-range crystalline order produced by subtle physical stability principles in certain kinds of clays are often rejected by critics, however, because there is a huge disparity in the amount of "information" involved.

"Information" … is not simply a mathematically definable concept or parameter, but is understood as such in relation to some coherent logic, within which its particular content … has a significant set of consequences or effects.

But the paradigm case of the weather shows that the *amount* of information required to specify the system is not the real issue. To describe a particular weather system in sufficient detail to offer fine-grained near-term or general long-term forecasts, we would need an inconceivably large and precise amount of data specifying the system's state (assuming we had a computational algorithm and a computer able to use it). In a sense, this data is "information-rich" and could easily require as much space in a computer as the storage of the information in a genome. Yet no one would argue that there is "information" in weather systems in the *same sense* as it exists in the genetic replication system. The reason is not a great disparity in the quantitative amount of "information" in the two types of systems, but rather the fact that in the genetic system, this "information" is clearly and coherently connected to significant functions or achievements of the organism carrying it, while we do not attribute to the weather any such rationally comprehensible function or achievement. "Information" is therefore not simply a mathematically definable concept or parameter, but is understood as such *in relation to some coherent logic*, within which its particular content (in contrast to some other, equally improbable particular contents) has a *significant* set of consequences or effects. In this sense, "information" is in the eye of the beholder (though this by no means discredits its objective reality). Thus, arguments about information in living things ultimately appeal to the idea of a logic of function, disjoint from the mechanistic principles of physics, which employs the data in question *as* information.

Tacit Role of "Functional Logic" in Current Biological Science

Research motivated by tacit use of a functional logic as meaningful for biosystems has developed beyond elementary stages. For example, what concepts have intellectual interest and explanatory value in genetic manipulation/transfer research? Structural characteristics and chemical mechanisms are necessary minimal knowledge about a strand of genetic material, but only provide an admission ticket to studying the function involved. When such material is inserted into a new biological context, the important question is whether it retains its functional capacity and integrity. A "functional logic" is the real, if tacit, topic of such research. It involves an altered paradigm of *scientific explanation.*

Conversation with acquaintances active in immunological or other medical biochemical work supports the same conclusion. Research program design in such fields is based on a tacit assumption that certain functional rules operate in biosystems—and learning what these rules are is the key to further progress. Understanding depends intimately on detailed chemical and structural knowledge, but the essential logic studied is functional and research jargon displays this. Entities are routinely described by names such as *receptor, messenger, trigger, sensor, label,* etc., as well as by simply mechanical terms from ordinary chemical dynamics such as *inhibitor* or *activator*. Molecular components enabling biological achievements are defined by their role in overall function of the system, not by what they are in themselves.

Long segments in DNA called *introns* are interspersed between genetically active sequences with recognized roles in protein or enzyme synthesis. Initially, it was proposed that these apparently inactive segments were merely "junk DNA"—material left over as the "molecular fossils" of evolution. However, more recent research has shown that though the role of introns is not yet understood, they have subtle effects; genetic material lacking them exhibits impaired function in some cases. When understood in greater detail, biological systems reveal a high degree of *economy* in physical structure used, *especially at a molecular level.* Some biologists explain this remarkable economy, and the resulting scantiness of a "molecular fossil record," by arguing that biosystems are incredibly efficient in using old and no longer essential subsystems as sources of "spare parts" for new tasks. But such language *tacitly presupposes an organizing logic of achievement* transcending physics.

Dialogue: Article

Legitimacy and Scope of "Naturalism" in Science Part II: Scope for New Scientific Paradigm

This essay does not aim to deny the "weak" evolutionary hypothesis that living things have emerged by some sort of process involving biological descent. Rather, I argue that the rules governing such unfolding are still largely unknown to us because they cannot be derived only from the mechanisms and constraints which physical science deals with. If biological systems are "machines" in a scientifically meaningful sense, they will be found to exhibit rules of proper function and organization, essentially a *logic of achievement*, employing the lower-level logic of physical structure and mechanisms for performing their higher level achievements. The scientific objectivity of such concepts, if they are valid, will be manifest in the more coherent understanding of biological systems they sponsor. I have argued here that learning such logic empirically from the study of living things is a legitimate scientific inquiry—and that biologists in many fields are already pursuing such studies without marking explicitly the paradigm change involved. Learning to do this, to rethink what we see in terms of such a new paradigm, offers us the opportunity to develop a different perspective on biological science, within which we may first understand better how living things function and develop as they are today. Only after such paradigm change transforms our understanding of biology would a more fruitful approach to the more difficult problem of origins be possible.

I have argued here that learning such logic empirically from the study of living things is a legitimate scientific inquiry—and that biologists in many fields are already pursuing such studies without marking explicitly the paradigm change involved.

I find some encouragement for views expressed here in Ernst Mayr's latest book, *This is Biology: The Science of the Living World*.[16] In sharp contrast to his earlier work, Mayr now stresses the inadequacy of reductionism in biology and the essential importance of a logic uniquely governing biological systems, which he sees clearly displayed in the genetic system. In the preface he says, concerning inanimate and living worlds:

> Both worlds obey the universal laws discovered and analyzed by the physical sciences, but living organisms obey also a second set of causes, the instructions from the genetic program. This second type of causation is nonexistent in the inanimate world.

Mayr's ideas about the *origins* of this "second set of causes" remain deeply committed to more traditional dogmas of evolution presented in his earlier works. His discussion of the vague general term "emergence" in the introduction to the book seems to offer refuge for the belief that such things have their roots in merely physical complexity. For me, Mayr's work is also seriously flawed by his misrepresentation of the ideas of both Polanyi and Elsasser as *"vitalism"*; actually, both thinkers were well ahead of him in recognizing the logically disjoint character of a true biological science. However, the emphasis Mayr now places on the reality and importance of such a "second set" of rules for understanding biology can only be constructive toward the ideas argued here. ◊

Notes

1 W. R. Thorson, "Legitimacy and Scope of 'Naturalism' in Science: Part I. Theological Basis for a 'Naturalistic' Science," *Perspectives on Science and Christian Faith* [This journal hereafter abbreviated as *PSCF*] 54 (March 2002): 3–13.

2 There is an extensive and growing literature on "intelligent design," bearing on both (a) its philosophical defense (vs. philosophical naturalism) and (b) its scientific justification. I do not cite this literature extensively here since I argue for a different approach to science, and do not agree with the project's main assumptions. As a well-known and rationally cogent example of argument for its *scientific justification*, see William A. Dembski, *Intelligent Design* (Downers Grove, IL: InterVarsity Press, 1999). For other citations bearing on the rejection of naturalism in science (notably, works by Phillip E. Johnson), see references listed in Ref. 1.

3 The view given here of Boyle's thinking about science is partly my interpretation, but has substantial historical basis. Cf. in particular Eugene M. Klaaren, *Religious Origins of Modern Science* (Grand Rapids, MI: Wm. B. Eerdmans Publishing Co., 1977) especially chapters 4, 5, & 6, and an Appendix of Boyle's works cited by the author. For additional brief references to Boyle's views, see R. Hooykaas, *Religion and the Rise of Modern Science* (Edinburgh, UK: Scottish Academic Press, 1972).

4 This interpretation of the effects of "mechanical philosophy" (and implicitly of the "naturalism" advocated by Boyle and Newton), and a view favoring a philosophy of science more Aristotelian in its assumptions, has been given wide currency by Nancy R. Pearcey and Charles B. Thaxton, *The Soul of Science: Christian Faith and Natural Philosophy* (Wheaton, IL: Good News Publishers, Crossway Books, 1994).

[5] A notable exception, of course, was Thomas Hobbes, whose thoroughgoing philosophical materialism was *anathema* to Boyle on the grounds it was atheistic. The issue was so important to Boyle that he was determined (successfully) to keep Hobbes from becoming a member of the Royal Society—a fact which supports the thesis that what really mattered in Boyle's view of a naturalistic science was setting it in a theological background context.

[6] See, for example, Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley, CA: University of California Press, 1984), esp. chap. 5; Colin A. Russell, *Cross-Currents: Interactions between Science and Faith* (Leicester, UK: Inter-Varsity Press, 1985), chap. 6, 109*ff*.

[7] Michael Polanyi, *Personal Knowledge: Toward a Post-critical Philosophy* (London, UK: Routledge and Kegan Paul, 1958), [paper ed., New York: Harper Torchbooks, Harper & Row Inc. (1977); and subsequent printings] esp. Parts I, II.

[8] Thomas S. Kuhn, *The Structure of Scientific Revolutions,* 2d ed. (Chicago, IL: University of Chicago Press, 1970).

[9] An example of such profound change, though it was still fairly minor compared to issues considered here, is the revolution in physics entailed in James Clerk Maxwell's theory of the electromagnetic field and the subsequent discovery by Einstein of special and general relativity theory (which belong to the same new horizon of meaning in physics). For a useful historical perspective on this, see the edited reprint of Clerk Maxwell's key paper, "A Dynamical Theory of the Electromagnetic Field," T. F. Torrance, ed.; especially, the introductory prefaces and commentary on Maxwell's work by both Torrance and Einstein (the latter at the centenary of Maxwell's birth in 1931) [Edinburgh, UK: Scottish Academic Press, (1982)]. Polanyi [Ref. 7, Part II, chap. 6] also points out that after Maxwell and Einstein, the token of meaning in physical theories shifted from the ideal of a mechanical model to that of a complex system of mathematical invariances, or *symmetry*. *But even in the case of this much less radical shift in thinking,* Maxwell's crucial ontological claim, i.e., that the equations of his new theory stood coherently on their own account as a description of a reality independent of that described by Newtonian mechanics, earned him reproach in private correspondence with William Thomson (later Lord Kelvin), who suggested that he was indulging in "mysticism."

[10] Walter M. Elsasser, *The Chief Abstractions of Biology* (Amsterdam, Netherlands: North-Holland Publishing Co., 1975).

[11] Michael Polanyi, *Personal Knowledge, op.cit.,* Ref. 7 above; cf. esp. Part IV, chap. 11, Sections 1–3. Polanyi's approach to epistemological questions is important to understanding what he means by arguing that there is a "logic of achievement" manifest in biological systems. Many people have read these comments and related speculations in his writing about the significance of life, as simply the expression by Polanyi of essentially religious or metaphysical beliefs radically critical of reductionism in modern science and the culture it has shaped. Of course, this is quite true, since Polanyi's understanding of "knowledge" as something *persons* hold is also an implicit critique of any reductionist or positivist world view. However, it is very important to realize that because of his whole approach to epistemology, Polanyi's view of the scope of *science* was also extremely *open*: He believed in the possibility of many distinct, logically independent levels of meaning in the world, whose *objective validity* can be apprehended and affirmed by persons through acts of "responsible fiduciary commitment." Hence, the idea that a "logic of achievement" has potential *scientific* significance is implicit in his claim that biosystems manifest such a logic.

[12] Michael J. Behe, *Darwin's Black Box: The Biochemical Challenge to Evolution* (New York: Free Press, 1996).

[13] Richard Dawkins, *The Blind Watchmaker* (London, UK: W. W. Norton, 1985). The claim of extreme Darwinism to account for biological complexity and variety by a gradualist process of random microscopic mutations reinforced by natural selection (the thesis of Dawkins' book) is really a philosophical speculation, which needs to be clearly distinguished from the much weaker (but scientifically more plausible) *general* hypothesis of "evolution"—the bare claim that living things have emerged by some (not fully specified) process involving biological descent from common ancestors. As critics with extremely diverse religious/philosophical beliefs point out, extreme Darwinism's thesis looks less and less credible against the background of relevant scientific facts and argument. Persistent, unwarranted public presentation of such speculative claims about the mechanism of evolution as though they were scientifically established should be vigorously criticized; they are really a kind of religious/philosophical myth about origins.

[14] Although the authors of the article do not consider the issues of interest here, a particularly beautiful example is provided by the detailed, incredibly efficient apparatus used by purple photosynthetic bacteria to convert visible light into chemically useful energy (Cf. Xiche Hu and Klaus Schulten, "How Nature Harvests Sunlight," *Physics Today* 50, no. 8 [August 1997]: 28–34). The energy transfer processes involved have been worked out in good detail in this case, and it is clear that the complex physical organization of the overall system is essential to its specific function of gathering multiple photons sequentially and using their accumulated energy to achieve a particular chemical reaction. The authors emphasize that the particular organization which makes this possible is highly specific; simpler precursors achieving the same task are not manifest.

[15] Behe's arguments using irreducible complexity to argue for intelligent design have been criticized by a number of writers arguing for an evolutionary explanation. See, for example, Kenneth R. Miller, *Finding Darwin's God: A Scientist's Search for Common Ground between God and Evolution* (New York: Harper Collins Publishers, 1999); and ongoing debate between Miller and Behe about examples/counterexamples of alleged/contested irreducible complexity is available on the Internet. Miller's criticisms however do not bear directly on the interpretation given here to the significance of irreducible complexity. He argues for the capability of evolutionary change in bacteria and similar simple organisms to account for such systems, without making any strong assertions about the detailed mechanisms. Such claims are not inconsistent with the idea of an embodied functional logic which can bring about such changes.

[16] Ernst Mayr, *This is Biology: The Science of the Living World* (Cambridge, MA: Harvard University Press, 1997).