

Teleology and Information in Biology

by

Phillip L. Engle

339 Concord Avenue
Greensburg PA 15601-1505
phillip.Engle@att.net
www.farfromequilibrium.com

October 3, 2002

presented at the e-symposium *The Teleological Origin of Biological Information*,
sponsored by the ISCID (International Society for Complexity, Information, and Design),
October 10-12, 2002

Revised October 17, 2002

© 2002 by Phillip L. Engle. All rights reserved.

ABSTRACT / INTRODUCTION

Teleology requires a “bracket out the object” methodology, as opposed to the “bracket out the subject” methodology of hard science. Information theory is ultimately a branch of epistemology, which brackets out neither the object nor the subject, but instead studies the interface between them. The same subject-matter (e.g., biological systems) can be studied from the radically diverse points of view of teleology, science, and information theory. Nevertheless these radically diverse viewpoints can be related to one another by means of analogs.

For example, the following are analogs: a “decision between two possible choices” in teleology, a “nonlinear bifurcation” in science, and a “bit” in information theory.

The following are also analogs: in teleology, a “conscious, decision-making being”; in science, a “nonlinear, hierarchical, complex physical system characterized at all levels by both external and internal conditional equifinality”; in information theory, a “creator and knower of information”.

Because neo-Darwinism is essentially a linear, stochastic/ deterministic theory which locates all biological chance at the microscopic level (e.g., “random mutations”) and all biological determinism at the macroscopic level (i.e., “natural selection”, resulting in differential rates of reproduction and mortality), its teleological analog is empty and featureless (i.e., “meaningless”), and moreover it can give no coherent non-tautological account of how biological information originates.

By contrast, Robert F. DeHaan’s nonlinear theory of evolution, called *macrodevelopment*, is rich in hierarchical teleological analogs and, via self-organization theory, is capable of immanently accounting for both the creation and storage of information by the biosphere. (The transcendent creation of this same information by a God having no complete analog within the physical universe is a valid, complementary teleological point-of-view.)

(Portions of this paper have been adapted from my book *Far From Equilibrium*, which can be found at www.laurelhighlandmedia.com .)¹

ANALOGS BETWEEN TELEOLOGY, SCIENCE, AND INFORMATION THEORY

The following subsections seek to establish some careful analogs between teleology, science, and information theory. The method used here does not seek to “wedge” teleological causes into science itself, and consequently it does not challenge methodological naturalism within science. In other words, this method does *not* speak the language of teleological entities (such as the mind) *causing* events in physical entities (such as the brain), nor on the other hand does it dismiss teleological entities as mere “epiphenomena” of physical processes, but rather it instead regards teleology, science, and information theory to be alternative, equally valid ways of describing “the same thing”.

Nevertheless the methodology we will be using here *does* suggest that where a scientific theory (such as neo-Darwinism) has *no* significant teleological analogs where such teleological analogs would certainly be expected, then that fact *by itself* constitutes significant evidence against that scientific theory.

Following, then, are a few teleological / scientific / informational analogs, ordered from the simpler to the more-complex:

Decision / Nonlinear Bifurcation / Bit

Our first “simple” example of a teleological / scientific / informational analog is the *decision / nonlinear bifurcation / bit*. In particular, we’ll look at the *pitchfork bifurcation*, following the discussion by Dilip Kondepudi and Ilya Prigogine in their book *Modern Thermodynamics*.² (This particular example will be taken as representative of a whole class of nonlinear complex physical systems, rather than as describing a particular physical system within a particular subject-matter area.)

Figure 1, below, depicts the *pitchfork bifurcation*:

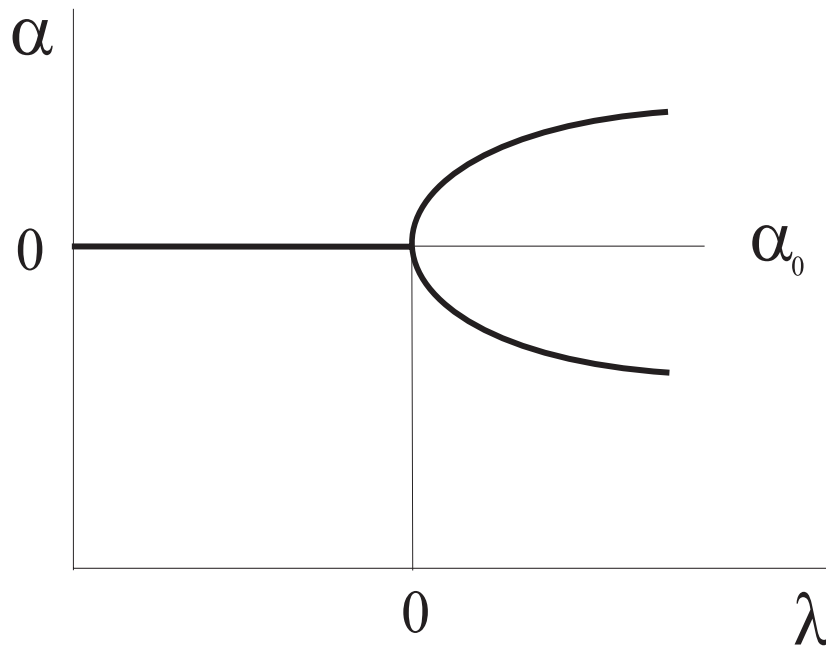


Figure 1 (after Figure 19.1 on page 429 of Kondepudi and Prigogine)

Consider the following nonlinear equation in the context of Figure 1:

$$d\alpha/dt = -\alpha^3 + \lambda\alpha \quad (1)$$

This equation is nonlinear with respect to the *internal* variable α because the rate of change in α with respect to time t , that is $d\alpha/dt$, is dependent on a higher power of α itself, namely α^3 . Furthermore the value of α is also dependent on the *external* variable λ , which we presume to be the “control variable” that is varied from outside the system in order to influence α . Now, as λ is varied from outside the system by increasing it from a negative value through zero and then up into the range of positive values, what happens to the “stationary solutions” of α (that is, those solutions of α for which $d\alpha/dt = 0$)? Starting from formula 1 above and setting $d\alpha/dt = 0$ we get:

$$0 = -\alpha^3 + \lambda\alpha \quad (2a)$$

$$\alpha^3 = \lambda\alpha \quad (2b)$$

$$\alpha^2 = \lambda \quad (2c)$$

$$\alpha = \pm \sqrt{\lambda} \text{ (or, also, } \alpha = 0 \text{ , as can be seen from 2a \& 2b)} \quad (2d)$$

Now, if we assume that, for physical reasons, α cannot be an imaginary number, it follows that, whenever the value of λ is less than zero, the only possible stationary solution of α is $\alpha = 0$, as is evident from Figure 1. However, if the value of λ becomes greater than zero, then there are *three* possible stationary solutions of α , as is also evident from Figure 1. Unfortunately only *two* of these stationary solutions are stable, namely $\alpha = \pm \sqrt{\lambda}$. By contrast, the stationary solution $\alpha = 0$ is *not* stable if λ is greater than 0. (The term “stable” in this context means that any small perturbation from the particular stationary solution of α decays, and the system falls back to that stationary solution, while “unstable” means that any such small perturbation from the stationary solution of α is magnified away from the stationary solution.)

The net result, as can be clearly seen in Figure 1, is that, as the control parameter λ is increased upwards from negative values and into the range of positive values, the value of the internal variable α *bifurcates* at $\lambda = 0$. That is, α begins to assume one of two possible stable values, either $+\sqrt{\lambda}$ or $-\sqrt{\lambda}$. (This particular kind of bifurcation is called a *pitchfork bifurcation*.)

As Kondepudi and Prigogine note:

The bifurcation of new solutions at exactly the point where one solution loses its stability is not a coincidence. It is a general property of the solutions of nonlinear equations. (This general relation between bifurcation and stability of solutions of nonlinear equations can be explained using *topological degree theory*, which is beyond the scope of this discussion.)³

Now, the key point here is that it is a matter of *immanent-objective chance* which of the two possible paths the internal variable α begins to take as the external control parameter λ is increased above zero: This internal macroscopic system *bifurcation* therefore cannot be dismissed as being “merely subjective”. To be sure, such a bifurcation would not be observed by a transcendent being (such as God) who had perfect knowledge of all variables and contingencies out to an infinite number of decimal places: For such a being, the system would remain absolutely determined, marred by no element of either macroscopic or microscopic chance. But science is done by imperfect finite beings who exist *within* the universe they are studying, and for such beings phenomena such as macroscopic absolute chance and irreversible time are *immanent-objective* facts.

In addition, even this present, relatively simple, example illustrates two characteristic features of many nonlinear complex physical systems, namely, both *external* and *internal conditional equifinality*:

This pitchfork-bifurcation system is subject to an *external* conditional constraint, namely, the value of the *external* control variable λ . However, this nonlinear system is also subject

to an *internal* conditional constraint, namely, which of two possible paths the *internal* variable α will take as the value of the external variable λ passes upwards through zero. Once the system starts along one or the other of these paths, however, it proceeds in a deterministic manner that may be equifinal with respect to that particular path. I say “may be” because, in more-complex nonlinear situations, the system will probably once again arrive at a bifurcation point that is characterized by absolute immanent-objective chance, conditionally split at that point, proceed deterministically for a while, and so on. In fact this structure, consisting of many nested *internal conditional equifinalities*, is quite common in those nonlinear complex physical systems which we will here call *tychistic* (i.e., those nonlinear systems which are dominantly deterministic, but which contain significant elements of absolute immanent-objective chance, as opposed to *chaotic* nonlinear systems, which are dominantly random, but contain significant elements of hidden determinism).

We may say, then, that one distinguishing feature of *tychistic* nonlinear complex physical systems is that they are often characterized by both external *and* internal conditional equifinality.

It is important to note, too, that although we have used the word “equifinality” in this context, there is *no* element of teleology in our present discussion: Rather, *everything* we have so far said involves only the proper scientific method of “bracketing out the subject” (nuanced perhaps by the fact that we *have* had to distinguish the viewpoint of immanent, imperfect beings from the viewpoint of a transcendent, perfect God).

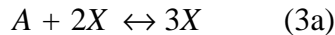
Nevertheless this physical, scientific fact of *internal conditional equifinality* within many *tychistic* nonlinear *physical* systems is obviously highly suggestive of interesting *teleological* systems that are *analogs* of those physical systems. For example, even with respect to the present pitchfork-bifurcation example it is very easy (and convincing) to make the teleological statement that the system *decided* to follow one of two possible paths in response to the upward change in the value of λ , and that thereafter the system pursued the *goal* represented by that path.

This strongly suggests the general principle that a teleological *decision* is often analogous to an instance of internal macroscopic *absolute chance* within the corresponding *tychistic* nonlinear physical system. Furthermore, it is easy to see that this analog, in turn, is commonly analogous to the concept of a *bit* (e.g., a 1 or a 0, a “yes” or a “no”) in information theory, thus completing our demonstration of the analogy *decision / nonlinear bifurcation / bit*.

Reversible Decision / Nonlinear Bistability / Binary Switch

Our next “simple” example of a teleological / scientific / informational analog is the *reversible decision / nonlinear bistability / binary switch*. (This example is taken from the book *Exploring Complexity* by Nicolis and Prigogine.⁴)

Consider the abstract chemical system represented by the following two chemical reactions, taken together:



Reaction 3a (in the forward direction) shows that one molecule of *A* combines with 2 molecules of *X* to form 3 molecules of *X*. This reaction can also proceed in the reverse direction (as is indicated by the double-headed arrow). At chemical equilibrium the reaction rates of these forward and reverse reactions always exactly balance out, a chemical principle known as *the principle of detailed balance*.

Reaction 3b (in the forward direction) shows that one molecule of *X* is transformed into one molecule of *B*. Again, the principle of detailed balance applies at chemical equilibrium with respect to the reaction in the reverse direction.

Notice too that the forward-reaction part of reaction 3a (i.e., reading left-to-right) is an example of *autocatalysis*: The more of *X* we have, the *more* of *X* we get, i.e., “The more of this the *more* of this.” By contrast the forward-reaction part of reaction 3b is an example of “*autoinhibition*” in the broadest sense: The more of *X* we have, the *less* of *X* we get, i.e., “The more of this the *less* of this.” (Technically, true *autoinhibition* refers to the case where a chemical inhibits the production of its own catalyst and thereby inhibits the production of itself, but we will here very loosely use the term to also include the common case where the reaction, in the forward direction, consumes and destroys the chemical.) This fine counterbalancing between an *autocatalytic* process on the one hand with an “*autoinhibitory*” process on the other is characteristic of many tychistic nonlinear complex physical systems. (For example, in biology, the key autocatalytic process is *reproduction*, while the key “*autoinhibitory*” process is *death*.)

Of course, if the autocatalytic process and the autoinhibitory process were to *exactly* counteract one another, then they would completely cancel each other out, and nothing interesting would happen. However, if these two processes are slightly *offset*, so that they are not simply the exact reverse of one another, then tychistic nonlinear physical phenomena of extraordinary complexity can occur.

The nonlinear aspects of the chemical reactions shown in 3a plus 3b above become evident when we write down the corresponding equations for the *rates of reaction*. Now, usually it is the case that the rate of a chemical reaction is directly proportional to the concentrations of the reactants *multiplied together*. This is so because the more concentrated the reactants, the more frequent are the collisions between the molecules and the more likely it

therefore is that the reaction will actually occur. Assuming in the present case that this proportionality holds, we will use a , b , and x to represent the concentrations of chemicals A , B , and X respectively, and we will use k_1 , k_2 , k_3 , and k_4 to represent the reaction-rate proportionality constants, with the odd-numbered constants corresponding to the forward reactions, and the even-numbered constants corresponding to the reverse reactions. (Such reaction-rate proportionality constants represent factors such as temperature, pressure, and the presence or absence of catalysts, all of which factors we will assume to be constant in this example.)

Since at chemical equilibrium *the principle of detailed balance* applies, so that the forward and reverse reactions of each reaction pair *taken individually* are exactly equal in reaction rate, the following reaction-rate equations are therefore each *individually* true for this system when it is at chemical equilibrium:

$$k_1 a x^2 = k_2 x^3 \quad (4a, \text{ which corresponds to the reactions in 3a})$$

$$k_3 x = k_4 b \quad (4b, \text{ which corresponds to the reactions in 3b})$$

We will also assume that we can control the concentrations a and b at will by continuously supplying and/or removing chemicals A and B from the system, so that concentration x is the only *dependent* variable in the system. The question then arises: What is the value of concentration x at chemical equilibrium (which we will call x_{eq}) for given values of a_{eq} , b_{eq} , k_1 , k_2 , k_3 , and k_4 ?

Assuming that x , k_2 , and k_3 are not equal to zero, we can use ordinary algebra to solve the simultaneous equations 4a and 4b above by dividing them as necessary with x , k_2 , and k_3 . The result is:

$$x_{\text{eq}} = k_4 b_{\text{eq}} / k_3 = k_1 a_{\text{eq}} / k_2 \quad (5)$$

Notice that this is a single, unique, determined solution for x_{eq} .

Furthermore, by algebraically rearranging the second equality in equation 5, we can see that our choice of a and b is not entirely free, if we want the system to attain chemical equilibrium. For the required *ratio* of a and b at chemical equilibrium is determined by the reaction-rate proportionality constants taken together:

$$b_{\text{eq}} / a_{\text{eq}} = k_1 k_3 / k_2 k_4 \quad (6)$$

But what if this chemical reaction system is driven by external constraints to a stationary state that is *far-from-equilibrium* rather than at or near equilibrium? In that case the principle of detailed balance does *not* apply. Instead, all that is required is that the effect of the two forward reactions *taken together* be exactly balanced by the effect of the two reverse reactions *taken together*. The resulting rate-of-reaction equation can be found by essentially *adding* equations 4a and 4b above as follows:

$$-k_2 x^3 + k_1 a x^2 = 0 \quad (7a, \text{ corresponding to 4a})$$

PLUS

$$-k_3x + k_4b = 0 \quad (7b, \text{ corresponding to } 4b)$$

EQUALS

$$-k_2x^3 + k_1ax^2 - k_3x + k_4b = 0 \quad (7c)$$

Now, equation 7c is a cubic (i.e., *nonlinear*) equation in x that can have as many as *three* solutions for certain values of a and b (two of these solutions being stable, and one being unstable) !

As Nicolis and Prigogine put it:

[N]on-equilibrium reveals the potentialities hidden in the nonlinearities, potentialities that remain dormant at or near equilibrium.⁵

If we now define a control parameter μ that is a suitable combination of the constant reaction-rate proportionality constants $k_1, k_2, k_3,$ and k_4 and the independently variable concentrations a and b , then Figure 2, below, shows how the *dependent* concentration x (at its far-from-equilibrium stationary state) varies as the combined *independent* control variable μ is altered:

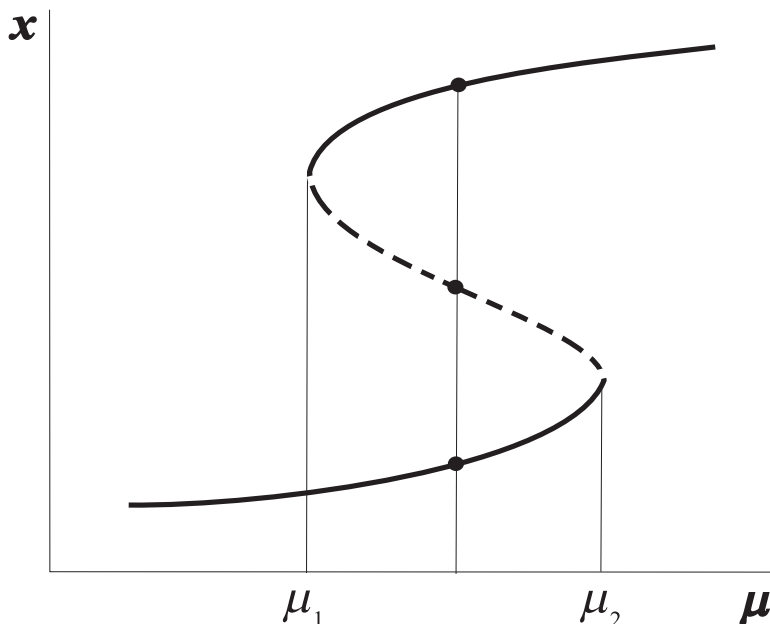


Figure 2 (after figure 75a on page 172 of Nicolis and Prigogine)

Notice that the graph in Figure 2 is S-shaped, as is often the case with cubic equations. Notice too that the middle portion of the graphed line is broken and dashed, indicating that these solutions for x are mathematically *unstable* in the sense that we defined in our pitchfork-bifurcation example. By contrast the solid portions of the graphed line (the upper and lower branches of the “S”) represent *stable* solutions of x .

Now, if we start with μ at a very low value, so that the value of x is on the lower branch of the “S”, and if we then slowly increase the value of μ , then the value of x moves slowly upward until μ reaches the value labeled as μ_2 in Figure 2. At that point the concentration of x jumps *suddenly upward*, and the system is instantly on the *upper* branch of the “S”. If, after μ has been increased above μ_2 , it is then slowly decreased below μ_2 , the value of x does *not* immediately jump back down to the lower branch of the “S”: Instead, the concentration x slowly goes down along the *upper* branch of the “S” until μ is taken down to the value μ_1 , at which point the concentration of x suddenly *drops downward* onto the lower branch of the “S”.

This example of a “simple” nonlinear chemical system illustrates three important features that are shared by many other tychistic nonlinear complex physical systems:

- Between the values μ_1 and μ_2 this system demonstrates the nonlinear phenomenon of *bistability*, since, for any given value of μ within this range, x can have one of *two* very different stable values.
- *Which* of these two stable values of x the system attains is entirely dependent on the *prior history* of the system, a scientific phenomenon known as *hysteresis*.⁶
- If that range of μ between μ_1 and μ_2 for which x is bistable is relatively narrow, then the control variable μ can act as a *binary switch*, reversibly switching the system discontinuously between a high concentration of x and a low concentration of x . In this way tychistic nonlinear physical systems can store binary information.

Nonlinear complex physical systems that display some or all of the above three features include transistors, lasers, and biological membranes.⁷

From our discussion in this subsection we may therefore rightly conclude that the following teleological / scientific / informational analog exists: *reversible decision / nonlinear bistability / binary switch*.

proximately match the forward path is because of the effects of bistability and hysteresis, which we just discussed in regard to Figure 2.) As Erich Jantsch has observed:

This implies a primitive, holistic *system memory* which appears already at the level of chemical reaction systems. The system “remembers” the initial conditions which made a particular development possible, the beginnings of each new structure in its evolution. We may say, the system is capable of *re-ligio*, the linking backward to its own origin. In linking backward, the system “relives” its own experience – not in separable details, but in a sequence of holistic . . . regimes.⁸

Thus teleological analogs to nonlinear chemical systems include not only *decisions* and *goals*, but *memory* and re-lived *history* as well ! Furthermore, this example clearly illustrates that *information storage* can be an informational analog to a nonlinear chemical system.

Another important point: Even though each “choice” made by the system as it moves from left to right in Figure 3 (i.e., *farther* from equilibrium) usually results in a relatively-sudden macroscopic continuity-breaking, accompanied by an equally sudden momentary decrease in system entropy, the amount of entropy internally produced by the system on a *continuous* basis actually *increases* after each such temporary entropy drop, due to the intensification of internal chemical reactions as we move up to each successive level of the far-from-equilibrium regime. As Kondepudi and Prigogine put it:

Each new structural instability generally increases the . . . entropy production in the system because it increases the number of reactions. This is in contrast to . . . near-equilibrium systems . . . in which the entropy production tends to a minimum. Structural instability may progressively drive far-from-equilibrium systems to higher states of entropy production and higher states of order. . . [I]nstability, fluctuation, and evolution to organized states is a general non-equilibrium process whose most spectacular manifestation is the evolution of life.⁹

Paralleling the evolution of the biosphere, one of the most awesome and spectacular examples of macroscopic continuity-breaking among nonlinear complex physical systems is the process of *morphogenesis*, i.e., the process by which the embryo of a living organism transforms from being comprised of generic *stem cells* to being comprised of a set of increasingly specific cells organized regionally into biological *organs*, each organ having a separate, but coordinated, biological function. Clearly this is not a linear, reductionistic, assembly-line process, but rather a nonlinear, holistic process that is characterized by *non-linear bifurcations*, *continuity-breaking*, and *conditional equifinality*.

As is typical of many other tychistic nonlinear physical processes, the *conditions* involved in morphogenesis are both *external* and *internal*: *External* conditions include the maintenance of the embryo’s temperature within a certain range, the supplying of the proper amount and kind of food to the embryo, etc. By contrast, *internal* conditions include all of the “decisions” which the embryo makes during its development, such as: the sex of the developing organism, which traits will be taken from the mother and which from the father, and so on.

Furthermore, the *equifinality* aspect of morphogenesis is shown by the fact that (as Hans Driesch discovered in the early 1900s) severely disturbing and rearranging some types of embryos at an *early* stage of their development does not affect the final outcome: The embryo still ultimately organizes itself in such a way as to develop normally.¹⁰ However, if the embryo is experimentally disturbed and rearranged at a *later* stage of its development, the embryo will *not* be able to recover and develop normally. This shows that *equifinality* is a key characteristic of morphogenesis, but that it is a *conditional equifinality* (in this case, *externally* conditional on *when* the embryo is experimentally disturbed and rearranged).

Note that not *every* nonlinear bifurcation is analogous to a teleological “decision”, but rather only those nonlinear bifurcations that have a significant element of *temporal* continuity-breaking (like the first and third of the detailed chemical examples I have just presented, and like the internal “decisions” of the embryo with respect to sex, etc.). If, on the contrary, a particular nonlinear bifurcation involves only (or primarily) *spatial* continuity-breaking, then that bifurcation may be called “pre-determined”, in the sense that multiple runs of the same experiment will (other things being equal) give essentially the same results at that bifurcation point. (In fact, most of the nonlinear bifurcations in morphogenesis are evidently of this “pre-determined” variety, which is why the process is so reliable in replicating complex biological individuals.)

The analog *memory / complex hysteresis / information storage*, which we have demonstrated in this subsection, can be extended into the following analog, which we stated in the introduction to this paper: in teleology, a “conscious, decision-making being”; in science, a “nonlinear, hierarchical, complex physical system characterized at all levels by both external and internal conditional equifinality”; in information theory, a “creator and knower of information”. Of course, the state of our knowledge is such that we are far from being able to demonstrate this extended analog in detail. Nevertheless, its appropriateness as a research program seems, at this point, clear.

Next, we will consider two competing theories of biological evolution in the light of our analogical approach to the relationship between teleology, science, and information theory: The first is the dominant theory of *neo-Darwinism*, while the second is Robert F. DeHaan’s upstart theory of *macrodevelopment*.

Neo-Darwinism is the first theory “up to bat” in the following section.

NEO-DARWINISM

Neo-Darwinism is the currently dominant, essentially *linear* theory of biological evolution. Neo-Darwinism builds on Charles Darwin's theory of evolution, as found especially in his famous book *On the Origin of the Species* (1st edition, 1859), but refines Darwin's theory through the use of the results of statistical *population genetics*, a field of study which was established by the Austrian monk and abbot Gregor Mendel (whose results became generally known only after 1900).

The basic principles of neo-Darwinism are often stated as follows:

1. Microscopic, *purely random* changes (such as mutations and copying errors) occur within the genetic code (*genotype*) of biological organisms, resulting in macroscopic variations in the physical characteristics (*phenotype*) of the individuals within the population of any given species. The vast majority of these purely random microscopic changes are harmful, but a very few are helpful in promoting the survival of the individual and therefore of the species of which that individual is a member.
2. Nature selects phenotypes by means of an essentially *deterministic* macroscopic process called *natural selection* (analogous to the artificial selection practiced by human breeders of plants and animals) according to the principle of the *survival of the fittest*: Those individuals of the species having phenotypes *favorable* to survival tend to produce offspring which carry the corresponding genotype on to the next generation. By contrast those individuals of the species having *unfavorable* phenotypes tend to die off before they can reproduce themselves. (This process of *natural selection* is often said to proceed by *trial-and-error*.)
3. By means of the above two basic principles, all of the various species (together with biological phyla, classes, families, etc.) comprising the biosphere have been created and transformed gradually, minutely, step-by-step throughout the earth's long history.

Now, a major problem with this formulation of neo-Darwinism lies in point 2. For it is evident that concepts such as *natural selection*, *survival of the fittest*, and *trial-and-error*, as stated, are really *teleological* concepts, rather than scientific concepts: Nature is being *personified* as a *conscious being* who *chooses* (i.e., *selects*) by *trial-and-error* which individuals of the species are to survive in accordance with a *goal* (i.e., *survival of the fittest*). We therefore need to recast neo-Darwinism into a scientific "bracket out the subject" formulation (rather than a "bracket out the object" teleological formulation) in order to consider it to be a truly scientific theory.

Fortunately the neo-Darwinists themselves have re-interpreted point 2 scientifically, as follows:

2. Different phenotypes among the individuals who comprise a species have statistically different rates of reproduction and statistically different rates of mortality. Phenotypes which have the *highest* rates of reproduction and/or the *lowest* rates of mortality tend to predominate within the species and pass their corresponding genotypes on to the next generation. Moreover, random microscopic changes to the genotype (as specified in point 1) constantly result in new macroscopic phenotypes which are then subjected to these same essentially deterministic processes of *differential reproduction* and *differential mortality*.

Notice in particular that in neo-Darwinism the element of objective, absolute chance is confined entirely to the *microscopic* world of the genotype, while determinism essentially rules in the *macroscopic* world of the phenotype in the form of the “iron law” of differential reproduction and differential mortality (“survival of the fittest”). In this respect neo-Darwinism somewhat resembles quantum theory, which is characterized by objective randomness at the sub-microscopic level encapsulated within the deterministic Schrodinger wave function at the macroscopic level. Another similarity between the two theories is that neo-Darwinism and quantum theory both rely heavily on the mathematics of statistics in their formulation.

By confining themselves to the realms of the deterministic and the stochastic (found at the opposite extremes of a “physical spectrum” that ranges, going left-to-right, from the deterministic to the tychistic to the chaotic to the stochastic), neo-Darwinism and quantum theory both manage to largely avoid the messy nonlinearities which characterize the tychistic and chaotic portions of this “physical spectrum”. For this reason they both are able to remain essentially *linear* physical theories. That is also why orthodox neo-Darwinists such as Richard Dawkins can describe living organisms as being “nothing but” mechanical, linear, reductionistic robots (albeit highly complex robots) that are driven deterministically by their “selfish genes”.

Of course neo-Darwinists are not entirely unaware that the mathematics which describes differential reproduction versus differential mortality can result in nonlinearities (for example, the famous *logistic equation* and the nonlinear *Lotka-Volterra predator-prey equations*). Nevertheless, neo-Darwinists almost always regard any elements of chance which happen to arise at the *macroscopic* level due to such nonlinearities to be “merely subjective”, an attitude which enables them to continue to view the macroscopic processes of differential reproduction and differential mortality as being *essentially* linear and deterministic. (As an exception to this generalization, the maverick neo-Darwinist Stephen Jay Gould *does* regard macroscopic absolute chance to objectively exist, but only *chaotically*, i.e., *not* within any teleologically meaningful context of external and internal conditional equifinality.)

The confining of objective, absolute chance entirely to the *microscopic* level, thus allowing objective determinism to essentially rule the *macroscopic* level, enables neo-Darwinists to

model the biosphere in such a way that *no teleologically “meaningful” analogs to anything in the biosphere are possible* (except, perhaps, for the weak “figure of speech” analog of nature “selecting” individuals and species for survival). This enables the neo-Darwinists (together with the quantum theorists) to present putatively conclusive proof that the universe is truly “meaningless and senseless” from a teleological point-of-view and that it is, in fact, a *teleological desert* in which the “radically autonomous” individual human self reigns supreme by default.

Yet the discussion of teleological / scientific / information-theory analogs in our previous section clearly suggests that the *absence* of meaningful teleological analogs to the biosphere as linearly conceived of by neo-Darwinism in fact constitutes very serious evidence *against* the neo-Darwinist theory, since the rich teleology of the biosphere is evident to practically everyone (except, apparently, to Anglo-American scientists of a reductionistic persuasion, who regard all such teleology to be mere illusion).

Significantly, putative proofs that step-by-step linear, reductionistic neo-Darwinian processes can create apparent teleological behavior (e.g., by approaching a *goal*) inevitably covertly introduce *nonlinear* entities and processes to provide the requisite future orientation and holism.

For example, Richard Dawkins, in his book *The Blind Watchmaker*, suggests a thought experiment in which a group of monkeys, each with his own typewriter, bangs out letters purely randomly, as they collectively attempt to generate the Shakespearean sentence “Methinks it is like a weasel”. David Berlinski describes the rest of Dawkins’ thought experiment as follows:

The Shakespearian target chosen by Dawkins - “Methinks it is like a weasel” - is a six word sentence containing 28 English letters (including the spaces). It occupies an isolated point in [phase] space of 10,000 million, million, million, million, million, million possibilities. . . .

Such are the fatal facts. The problem confronting the monkeys is, of course, a double one: they must, to be sure, find the right letters, but they cannot lose the right letters once they have found them. A random search in a [phase] space of this size is an exercise in irrelevance. This is something the monkeys appear to know. What more, then, is expected; what more required? *Cumulative* selection, Dawkins argues – the answer offered as well by Stephen Jay Gould, Manfred Eigen, and Daniel Dennett. The experiment now proceeds in stages. The monkeys type randomly. After a time, they are allowed to survey what they have typed in order to choose the result “which *however slightly* most resembles the target phrase”. It is a computer that in Dawkins’ experiment performs the crucial assessments . . . The process under way is one in which stray successes are spotted and then saved. This process is iterated and iterated again. Variations close to the target are conserved *because* they are close to the target. . . until, with the appearance of a miracle in progress, randomly derived sentences do begin to converge on the target sentence itself. . . .

The entire exercise is, however, an achievement in self-deception. A *target* phrase? Iterations that *most resemble* the target? . . . If things are sightless, how is the target represented, and how is the distance between randomly generated phrases and targets assessed? And by whom? . . .¹¹

As Berlinski points out, all such neo-Darwinian “thought experiments” covertly introduce a conscious “selector” (supposedly analogous to nature as “natural selector”) who guides the experiment to its successful conclusion. In Dawkins’ case this “selector” is a computer *that has been programmed by a human being as an extension of that human being’s consciousness and will*. This “selector” selects in such a way that a *future goal* (such as the completion of the sentence “Methinks it is like a weasel”) will be arrived at. But neo-Darwinian deterministic/stochastic processes are fundamentally incapable of such a future orientation: Only a nonlinear tychistic system (in this case, a human body & brain extended via a computer) can have the requisite future orientation, by virtue of its temporal (and spatial) holism, together with its external and internal conditional equifinality. Again, David Berlinski:

Favorable changes are one thing; changes that *will* be favorable, another. If the mechanism of Darwinian evolution is restricted to changes that are favorable at the time they are selected, I see no reason to suppose that it could produce any fancy structures whatsoever. If the mechanism is permitted to incorporate changes that are neutral at the time of selection, but will be favorable some time in the future, I see no reason to consider the process Darwinian.¹²

Neo-Darwinians have come up with more-subtle versions of Dawkins’ thought experiment (such as the one in Thomas Schneider’s article “Evolution of Biological Information”,¹³ where the experimenter’s choice of a fitness function is the covertly-introduced nonlinear/teleological element), but in the end all such attempts to derive apparently teleological behavior from purely linear stochastic/deterministic neo-Darwinian mechanisms have failed, as William A. Dembski¹⁴ and others have clearly demonstrated.

The heart of the neo-Darwinist dilemma is therefore this: If the neo-Darwinist is serious about personifying nature as a conscious “natural selector”, then he must be equally serious in regarding macroscopic nature to be a hierarchical, nonlinear, holistic, tychistic physical system. But this contradicts one of neo-Darwinism’s fundamental postulates, namely, that macroscopically nature is essentially *linear, mechanical, and deterministic*. On the other hand, if the neo-Darwinist is serious in maintaining that the twin macroscopic natural processes of differential reproduction and differential mortality are essentially *linear and deterministic* in their sorting of the results of microscopic random genetic variations, then *personifying* these putatively deterministic processes as “natural selection” in order to imply a nonexistent future-orientation for them is illicit and is, in Berlinski’s words, “an achievement in self-deception”.

For similar reasons, mechanistic, linear, step-by-step neo-Darwinism can give no coherent account of the origin of biological information: Recent proofs within the past five years of the so-called “no free lunch” theorems have shown that blind-search evolutionary algorithms of the type required by neo-Darwinism cannot create “interesting” information without “fine-tuning” by a nonlinear/teleological agent. As William A. Dembski puts it in the introduction to his recent book, *No Free Lunch*:

The upshot of these theorems is that evolutionary algorithms, far from being universal problem solvers, are in fact quite limited problem solvers that depend crucially

on additional information not inherent in the algorithms before they are able to solve any interesting problems. This additional information needs to be carefully specified and fine-tuned, and such specification and fine-tuning is always thoroughly teleological. Consequently, evolutionary algorithms are incapable of providing a computational justification for the Darwinian mechanism of natural selection and random variation as the primary creative force in biology.¹⁵

In the chapter called “The Ten Facts of Evolution” in my own book *Far From Equilibrium*,¹⁶ I relentlessly detail (on many other grounds) the massive failure of neo-Darwinism to explain biological evolution. Perhaps the essential point is that, while neo-Darwinism is *correct* in stressing the centrality of differential reproduction and differential mortality in biological evolution, it is *incorrect* in regarding these processes to be essentially reductionistic, linear, and *deterministic* (or, alternatively, in Stephen Jay Gould’s formulation, nonlinearly *chaotic*), rather than being nonlinearly *tychistic*.

Clearly a new theory of evolution is needed. Fortunately such a new theory of evolution has been proposed by Robert F. DeHaan, namely his theory of *macrodevelopment*, which is the subject of the following section.

MACRODEVELOPMENT

The nonlinear David which we have chosen to oppose the linear Goliath of neo-Darwinism is Robert F. DeHaan's theory of *macrodevelopment*, which he first presented in three articles in 1996 and 1997.¹⁷ Note that our terminology will differ somewhat from DeHaan's in that DeHaan uses the term "evolution" to essentially mean what we have called the *theory* of neo-Darwinism, while by contrast we are using the term "evolution" to denote the *fact* of transformation of life forms over millions of years. (In other words, for us, "evolution" is the *fact* which the respective *theories* of neo-Darwinism and macrodevelopment are competing to explain.) Furthermore, DeHaan is willing to concede that neo-Darwinian mechanisms play a role in the evolution of *species* (as opposed to higher taxonomic categories such as phyla and families), whereas we will view neo-Darwinian mechanisms as effective *only* in creating and preserving *varieties within* species.

Here, then, are the basic principles of the theory of *macrodevelopment*:

1. The evolution of life on earth over millions of years is essentially a *nonlinear tychistic* process which is analogous to the nonlinear process of individual embryonic development (*morphogenesis*). In other words, the irreversible nonlinear *macrodevelopment* of the biosphere over millions of years parallels in important ways the irreversible nonlinear *microdevelopment* of the individual biological organism over its lifetime (especially during its embryonic stage).
2. One important parallel between macrodevelopment and microdevelopment is the manner in which the overall *body plans* of biological organisms (corresponding to the *phylum* taxon-level) appeared rapidly during the Cambrian era and the correspondingly rapid manner in which the overall *body plan* of the individual is established during morphogenesis. (That is why Robert F. DeHaan calls Cambrian animals *stem animals*, analogous to the *stem cells* in the individual embryo.) DeHaan explains:

Both individuals and phyletic lineages begin with a general body plan. The body plan is among the first structures to appear in the individual embryological development. The earliest and defining feature of the Cambrian animals was their basic body plan.

Both individuals and phyletic lineages develop very rapidly at the start. Early development in the embryo is extremely rapid. In human beings all systems and morphological features are in place in slightly more than three months after conception. The formation of body plans in the Cambrian [era] occurred with extreme rapidity, geologically speaking, paralleling the very rapid formation of the body plan early in individual embryonic development and growth.¹⁸

3. The parallels between macrodevelopment and microdevelopment are not confined to the embryonic stage, but extend to the entire span of the individual's life, from birth until death. Again, Robert F. DeHaan:

The entire life span of individual animals is a manifestation of development. All organisms start small and simple at conception, rise rapidly through

the prenatal and juvenile stages, grow large and complex, reach a rounded maximum on many variables in maturity, decline in old age, and eventually die. The rise and subsequent decline is an invariant characteristic of lifelong individual development.

There is also an unvarying succession of changes in ancestral lineages, starting with a few, small, insignificant animals, that increase in size, complexity, population density, and on many other dimensions; reach a rounded maximum, and then decline to fewer, smaller, less robust groups. This orderly sequence is isomorphic to development in the individual life span. . . .

In short, the overall shape of individual development and the general shape of ancestral lineages are remarkably similar. The only major difference between them is the time scale: enormous for the historical lineages, insignificantly short for the individual organisms. The resemblance between large-scale sequences of [ancestral] changes covering millions of years and the sequence of changes in [the] early embryonic and lifelong development of individual organisms is quite astounding. It cannot be a meaningless coincidence that so many phyletic patterns of change in the fossil record are found to resemble patterns of development found in individual organisms. These similarities are surely not trivial or merely coincidental. On the contrary, they point to a deep unity between the overarching historical processes, called macrodevelopment, and small-scale individual development. Patterns in the fossil record are sufficiently similar to [the] patterns in [the] development of individual organisms that those in the fossil record can provisionally be considered [to be] the results of development on a large historical scale.¹⁹

4. The evolution of the biosphere has proceeded via a long historical series of nonlinear continuity-breaking bifurcations. In each of these bifurcations a *single* instance of a *more-generic* taxon (i.e., kingdom, phylum, class, order, family, genus, or species) has split into *two* instances of taxa at the *next most-specific* level. As a result of this split, the more-generic ancestral taxon continues to exist only in the form of the generic features of the two more-specific taxa into which it has split. That is why the splitting of taxa in accordance with the process of macrodevelopment is a process of *symmetrical* splitting in which the “ancestor” taxon ceases to independently exist. (By contrast, neo-Darwinism proposes that new taxa *split off* from previous taxa, leaving the older ancestral taxon to continue to independently exist and evolve. Neo-Darwinian taxonomic splits are therefore inevitably *asymmetrical*, whether the version of neo-Darwinism is the phyletic gradualism of Darwin, the punctuated equilibrium of Nilas Eldredge and Stephen Jay Gould, or even the “hopeful monster” theory of Richard Goldschmidt.) Two important points:
 - When a more-generic taxon splits into two more-specific taxa, those more-specific taxa need not be at the next-most-specific *named* level. In other words, a phylum need not split into two classes, a class need not split into two orders, and so on. (This is because there are far too many taxonomic levels to be able to actually *name* them all.)

Nevertheless the *direction* of the splits is always from the *generic* to the *specific*.

- The more-generic animals and plants of the past were not necessarily “bland” than the animals and plants of today: Contemporarily they may have had all of the particularity of today’s animals and plants. However, the traits comprising that exact particularity were irrevocably lost to the future as a result of the taxon-splitting process.
5. Each taxonomic bifurcation within the biosphere is a holistic, taxon-wide phenomenon of nonlinear continuity-breaking that occurs within one (or a few) generations: It does *not* occur gradually, minutely, and mechanically, as neo-Darwinism proposes, but rather *suddenly* and *holistically*, like the sudden holistic reorganizations that occur periodically during the course of individual morphogenesis.
 6. It is probably true that taxon-wide nonlinear bifurcations within the biosphere do not occur today. Nevertheless they were once a prominent feature of the biosphere’s past.
 7. Genetic evidence strongly supports the macrodevelopment hypothesis (especially when we exclude the individualistic “hopeful monster” hypothesis, essentially because it requires taxonomic “splitting off”). This genetic evidence includes: *polyploid speciation* events among contemporary plants; at least two major *tetraploid events* within the evolutionary history of vertebrates, one associated with the evolutionary emergence of jawless fish and the other associated with the evolutionary emergence of the four-limbed vertebrates, a.k.a. tetrapods (Susumu Ohno, 1970); the *structure of the differences between the DNA of closely-related species* (typically characterized by long, identical segments of DNA that are rearranged and/or “flipped” relative to one another, rather than differing by point mutations, as neo-Darwinism would suggest); and, finally, John A. Davison’s evidence for the involvement of *semi-meiosis* in the “origin of the species”.
 8. Neo-Darwinian mechanisms, described in the previous section, only succeed in changing the statistical distribution of phenotypes *within* the species. This change in the statistical distribution of intra-species varieties occurs as a continuous process of adaptation to the environment. However, all such statistical changes are almost-instantly *reversible* if the environment reverts back to its former state. Therefore, calling such changes “microevolution” (as is often done) is a misnomer, since true biological evolution is essentially a nonlinear *immanently irreversible* process.
 9. Biological systems (including the biosphere as-a-whole) are highly complex, hierarchical, holistic, open, tychistic, nonlinear systems, rather than being either the macroscopically deterministic and microscopically stochastic systems

assumed by orthodox neo-Darwinism or the nonlinear chaotic systems assumed by the “heretical” neo-Darwinism of Stephen Jay Gould.

The above nine points express the essence of the theory of *macrodevelopment* as used in this paper. Points 1 through 3 are essentially the same as Robert F. DeHaan’s original theory of macrodevelopment, while points 4 through 9 represent expansions of DeHaan’s original theory with which DeHaan himself may or may not agree.

DeHaan is careful to distinguish his theory of *macrodevelopment* from a theory which superficially seems to be similar, namely, the so-called *biogenic law*, popularly expressed as “ontogeny recapitulates phylogeny”:

[Macrodevelopment] is not a warmed-over version of the so-called biogenic law, popularized by the slogan “ontogeny recapitulates phylogeny”. This outmoded “law of recapitulation”, formulated by Ernst Haeckel (1834-1919), held that there is a one-to-one correspondence between phylogeny and ontogeny; that each organism in its development from zygote to adult repeats its phyletic history in condensed form, i.e., climbs its own family tree, so to speak. Raff described the biogenic law more technically as follows: “All animals should recapitulate their phylogenies in an abbreviated form during development, and developmental stages should reveal those histories.”

[Macrodevelopment], however, is not concerned with trying to find replications of exact stages of phyletic transformation in the development of individual organisms; rather, it focuses on generalized processes and patterns that are universal across all lineages.²⁰

DeHaan also distinguishes his theory of *macrodevelopment* from an earlier theory called *orthogenesis*:

[Macrodevelopment] is distantly related to ideas that were held in the 1920s by several paleontologists. [Niles] Eldredge reported the situation as follows:

Paleontologists have had an abiding interest in long-term evolutionary trends that struck Cope and many others as linear or “rectilinear”. “Orthogenesis”, a term coined by Haacke (1893; fide Simpson 1944), describes a pattern of linear directional change in phylogeny, a pattern generally thought in pre-synthesis days to reflect internal evolutionary processes. This line of thinking, at least in paleontological circles, reached its culmination in the work of vertebrate paleontologist Henry Fairfield Osborn, whose theory of orthogenesis (later called “aristogenesis”) saw linear evolutionary change arising from within organisms themselves, a mechanism, moreover, taking precedence over natural selection if not supplanting it altogether.

The general theory of [macrodevelopment] is an advance over the earlier ideas of “orthogenesis” and “aristogenesis” because it (1) is a multidimensional concept; it identifies many different kinds of long-term trends that are parallel to individual development, and because it (2) relates the process to real causal genetic mechanisms.²¹

We may expand on DeHaan’s remarks by noting that from Eldredge’s description it appears that orthogenesis was viewed as being a *linear*, mechanical (albeit internal) process, whereas by contrast macrodevelopment is an inherently holistic, *nonlinear* process.

In addition, we may distinguish the theory of macrodevelopment from the work being done on evolution by Stuart Kauffman and others at the Santa Fe Institute: Their work *does* contain a high awareness of the presence of nonlinearity in the biosphere. However, their work is also almost entirely confined to a statistical population-genetics approach, which has had the effect of enmeshing them in residual stochastic/deterministic neo-Darwinian assumptions.

Much closer to the theory of macrodevelopment (and, indeed, important confirmation of it) is recent work done by the famous mathematician Ian Stewart and his biologist collaborator Jack Cohen. It all started when Cohen asked Stewart about nonlinear “symmetry breaking” (i.e., what we are calling nonlinear macroscopic “continuity-breaking”). After Stewart replied, Cohen remarked: “Speciation - that’s symmetry breaking, isn’t it?” Ian Stewart explains what happened next:

First I thought he didn’t understand what I was talking about. Then I asked him what he meant. He said: If you’ve got one species, that’s a very symmetric situation, because all the animals are pretty much the same, but two species must be less symmetric.

We’ve written a few papers about this as a mathematical metaphor for speciation, modeling a species as identical organisms and worrying about the differences between individuals later on. These models turn out to include a general mathematical process, called *bifurcation*, where the state of the system changes quite dramatically, even though the system’s environment only changes a small amount.

The models produce some general predictions: the split happens very fast, on an evolutionary timescale, and the two new species ‘pull apart’ in opposite directions compared with the original. For instance, if the original species is a bird with a medium-sized beak, then the species splits into one with a big beak and one with a small. The average size of beak doesn’t change at all.

Until very recently, I’d have left that as a metaphor. . . [But now it] looks as if it’s going to go beyond metaphor and into science.²²

The theory of macrodevelopment has even (to some extent) been anticipated by the noted critic of neo-Darwinism and advocate of intelligent design, Phillip E. Johnson, who writes:

Certain features, like the existence of natural groups and common “junk DNA” sequences, support an inference that there was some sort of process of development [of species] from some common source. We may call that process “common ancestry”, but it does not necessarily follow that we are referring to the ordinary process of reproduction that we observe in today’s world, where ancestors give birth to descendants very much like themselves. Normal reproduction is not known to produce radically new organs or organisms, and if it did so it would have to proceed one tiny step at a time. In fact there is a great deal of evidence that innovative transformations must have involved organisms doing something “different from what they ordinarily do”.²³

Finally, we need to stress how limited is the present constituency for the theory of macrodevelopment, or indeed for any other *nonlinear* theory of biological evolution. Orthodox neo-Darwinists are thoroughly entrenched in the Anglo-American scientific estab-

ishment and have multi-millions of dollars (together with vast non-monetary resources) at their disposal. (Witness, as one small example, the recent 8-hour PBS series *Evolution*, which was financed by a reported *15-million dollar* donation from Microsoft co-founder Paul Allen.) Even believers in special creation and intelligent design have a not-insignificant constituency and, consequently, a not-insignificant monetary base.

By contrast there is virtually *no* political or scientific constituency for the theory of macrodevelopment (even though Robert F. DeHaan regards himself to be a part of the “intelligent design” movement). When I wrote to DeHaan in November of 2000 to inquire if he had completed any full-length book on macrodevelopment, he wrote back: “I completed a book-length MS on this subject several years ago and submitted a summary of it to every publisher I could find, both here and abroad. To no avail.” In addition to his finished unpublished book on the overall subject of macrodevelopment, DeHaan is currently working on a book on what he calls *phylogerontology*. This second book will deal in far greater detail with the analogies between the later stages in the life of individual organisms (as they move towards death) and the later stages in the life of taxonomic lineages.²⁴

In the chapter of my book *Far From Equilibrium* called “The Ten Facts of Evolution” I relentlessly compare the evidence for and against the evolutionary theory of neo-Darwinism with the evidence for and against the evolutionary theory of macrodevelopment: Macrodevelopment wins hands down.²⁵ (See also www.farfromequilibrium.com)

Now, we saw in the previous section that the biosphere as scientifically conceived of by neo-Darwinism has *no* meaningful teleological or informational analogs, and we noted this as a significant piece of evidence *against* the theory. By contrast, the rich teleological and informational analogs to macrodevelopment will be discussed in the following two sections.

TELEOLOGICAL ANALOGS TO MACRODEVELOPMENT

Point 9 of our basic description of macrodevelopment in the previous section states that:

Biological systems (including the biosphere as-a-whole) are highly complex, hierarchical, holistic, open, tychistic, nonlinear systems, rather than being either the macroscopically deterministic and microscopically stochastic systems assumed by orthodox neo-Darwinism or the nonlinear chaotic systems assumed by the “heretical” neo-Darwinism of Stephen Jay Gould.

Now, naturalistic scientific explanations of the biosphere imply that the teleological analog of the biosphere is purposeless and meaningless *only if* the biosphere is regarded *either* to be the result of microscopically stochastic and macroscopically deterministic processes (as in Richard Dawkins’ orthodox neo-Darwinism) *or* to be the result of *chaotic* nonlinear processes (as in Stephen Jay Gould’s heretical neo-Darwinism). If, on the other hand, the biosphere is the result of *tychistic* nonlinear processes (that is, nonlinear processes in which order dominates over disorder, thus creating a hierarchy of entities that are characterized by both external *and* internal conditional equifinality at all hierarchical levels, up to and including the level of the biosphere as-a-whole), then the teleological analog to the biosphere is seen to be an inclusive hierarchy of countless *group subjects* that make decisions, have goals & purposes, and so on. In such a case, we may regard the biosphere, from an *immanent* teleological point-of-view, to be the result of *self-organization*, where we take the term *self* quite seriously, rather than merely metaphorically. (This is not to say, of course, that a cell has the *same* level of consciousness as a human being, but it does have *some* level of consciousness.)

Furthermore, it is clear that this *self-organization thesis* (which we will abbreviate, tongue-in-cheek, as SOT), while continuing to be closely tied to the naturalistic and scientific, nevertheless implies that the biosphere is rich in teleological purpose and meaning at all levels, quite contrary to neo-Darwinism. It is also clear that, if this self-organization thesis is true, then so-called “primitive peoples” were not so far wrong in believing in *animism* and that Aristotle’s attempt at constructing a natural, hierarchical *teleological biology* was not a foolish enterprise. Most importantly for our present purposes, these considerations demonstrate that the self-organization thesis (or SOT) is the main *immanent teleological* analog of the *scientific* theory of macrodevelopment.

By identifying the SOT as an *immanent teleology*, I mean that it is true only from the point of view of finite teleological beings having physical analogs *within* the physical universe: It needs to be supplemented by the *intelligent design thesis* (usually abbreviated as IDT) as the corresponding *transcendent teleology*, which is true from the point of view of a perfect divine being (e.g., God) who is transcendent with respect to the physical universe.

In other words, the SOT is correct with respect to *immanent* scientific/teleological truth, while the IDT is correct with respect to *transcendent* scientific/teleological truth. This is so because the SOT relates *physically* to moments of chance that are *immanently* objective with respect to imperfect, immanent beings who can measure only out to a *finite* number of decimal places, and relates *teleologically* to the *decisions* (made by immanent sub-

jects) that *analogically correspond* to those physical moments of chance. By contrast the IDT relates *physically* to God's *transcendently deterministic* view of the physical universe out to an *infinite* number of decimal places, and relates *teleologically* to God's corresponding omniscient, all-determining will and creative power, which "intelligently designs" the universe from beyond its immanent confines. (This distinction between an *immanent* point-of-view and a *transcendent* point-of-view is frequently of importance in scientific, philosophical, and theological discussions, for example, in the discussion of the problem of theodicy, or in the discussion of the problem of human "free-will" vs. divine "pre-destination".)

Unfortunately, at the present time, most IDT theorists are as hostile to the SOT as are the orthodox neo-Darwinists, since both groups typically share the common view (deriving from the Enlightenment) that, at bottom, the physical universe is "nothing but" a linear (albeit complex) machine: They only disagree as to whether teleological causation (in the form of an "intelligent designer") should be allowed within science itself.

For the most part IDT theorists and orthodox neo-Darwinists try to ignore nonlinear science and the SOT by brushing them off as just "playing around with computers", since (of course) nonlinear science generally cannot produce *deterministic* predictions, nor can nonlinear models *exactly* replicate a given physical system, since in nonlinear scientific models immanently-objective *absolute chance* is generally intermixed with determinism at the same hierarchical level. (Typical of these brush-offs is P. Hohenberg's oft-quoted remark concerning Ilya Prigogine's theory of nonlinear thermodynamics and dissipative structures: "I don't know of a single phenomenon his theory has explained", a remark made *after* Prigogine won the Nobel Prize in chemistry!)

Occasionally, however, a direct refutation of the SOT is attempted, as in the following argument from Stephen C. Meyer's article "DNA and other Designs":

Ironically, perhaps the most prominent early advocate of self-organization, Dean Kenyon, has now explicitly repudiated such theories as both incompatible with empirical findings and theoretically incoherent.

The empirical difficulties that attend self-organizational scenarios can be illustrated by examining a DNA molecule. . . . There are bonds, for example, between the sugar and the phosphate molecules that form the two twisting backbones of the DNA molecule. There are bonds fixing individual (nucleotide) bases to the sugar-phosphate backbones on each side of the molecule. Notice that there are no chemical bonds between the bases that run along the spine of the helix. Yet it is precisely along this axis of the molecule that the genetic instructions in DNA are encoded.

Further, just as magnetic letters can be combined and recombined in any way to form various sequences on a metal surface, so too can each of the four bases A, T, G, and C attach to any site on the DNA backbone with equal facility, making all sequences equally probable (or improbable). The same type of chemical bond occurs between the bases and the backbone regardless of which base attaches. All four bases are acceptable; none is preferred. In other words, differential bonding affinities do not account for the sequencing of the bases. Because these same facts hold for RNA molecules, researchers who speculate that life began in an "RNA world" have also failed to solve the sequencing problem – i.e., the problem of explaining how information present in all functioning RNA molecules could have arisen in the first place.

For those who want to explain the origin of life as the result of self-organizing properties intrinsic to the material constituents of living systems, these rather elementary facts of molecular biology have devastating implications. The most logical place to look for self-organizing properties to explain the origin of genetic information is in the constituent parts of the molecules carrying that information. But biochemistry and molecular biology make clear that the forces of attraction between the constituents in DNA, RNA, and protein do not explain the sequence specificity of these large information-bearing biomolecules.

Significantly, information theorists insist that there is a good reason for this. If chemical affinities between the constituents in the DNA message text determined the arrangement of the text, such affinities would dramatically diminish the capacity of DNA to carry information. . . .

. . . Bonding affinities, to the extent they exist, mitigate against the maximization of information. They cannot, therefore, be used to explain the origin of information. . . .

The tendency to confuse the qualitative distinction between “order” and “information” has characterized self-organizational research efforts and calls into question the relevance of such work to the origin of life. Self-organizational theorists explain well what doesn’t need explaining. What needs explaining is not the origin of order . . . , but the origin of *information* – the highly improbable, aperiodic, and yet specified sequences that make biological function possible.

. . . Systems that are characterized by both specificity and complexity (what information theorists call “specified complexity”) have “information content”. Since such systems have the qualitative feature of aperiodicity or complexity, they are qualitatively distinguishable from systems characterized by simple periodic order. Thus, attempts to explain the origin of order have no relevance to discussions of the origin of information content.²⁶

Meyer’s attack on the self-organizational thesis (SOT) can be refuted as follows:

1. Vague attacks on the SOT as “incompatible with empirical findings and theoretically incoherent” amount to name-calling and are unworthy of refutation.
2. The fact that the forces of chemical bonding within the DNA molecule do not determine the order of the nucleotides along the DNA spine only means that the order of those nucleotides was specified (from a *scientific* point-of-view) by physical, holistic, nonlinear tychistic processes operating at an organizational level *higher than that of the DNA molecule itself*: This fact, therefore, *in no way* refutes the SOT.
3. Meyer’s accusation that SOT theorists are only studying “order” and not “information” is puzzling. It’s true that, from a scientific perspective, SOT theorists are not *directly* studying “information”, but that is only because they recognize that “information” is an *epistemological* concept and not a *scientific* concept. However, in addition to the presence of *order*, SOT theorists most definitely *do* recognize the equally important presence of significant *novelty* and

microscopic & macroscopic *chance* within biological systems: That is why the SOT definition of *complexity* (whose epistemological analog is “information”) locates maximum complexity (and therefore maximum “information”) in the exact middle of what we have called “the physical spectrum”, i.e., at the right edge of tychism and the left edge of chaos (rather than at the far right edge of stochastic randomness, as is done in the *algorithmic* definition of complexity).

(Implicit in this last point, point 3, is the important idea that even a non-semantic definition of the concept of “information” ought to locate the *maximum* of information, not at maximum randomness, as in the standard Shannon & Chaitin-Kolmogorov-Solomonoff formulations, but rather at a point exactly *midway* between all-ones or all-zeros on the far left and a completely random mixture of ones-and-zeros on the far right.)

Hopefully an increase in both the quantity and quality of the dialog between IDT and SOT theorists will help to clear up the above kinds of misunderstandings in the future. One hopeful sign that this is beginning to happen is the cordial debate/dialog that occurred on November 13, 2001 at the University of New Mexico in Albuquerque NM between William Dembski (representing the IDT) and Stuart Kauffman (representing the SOT).²⁷

To conclude this section, if you are an IDT theorist who continues to wish to regard the SOT as your mortal enemy, rather than as your friend, please consider carefully your answers to the following questions:

- From a *transcendent* point-of-view, God is the creator (i.e., the “sender”) of the information stored in biological DNA. But who is the *receiver*? Is DNA just a “scratch pad” where God stores information he wants to remember later? Or is the *receiver* the biological individual specified by his DNA? But if this biological individual (whether human or nonhuman, at whatever hierarchical biological level) is a *receiver* of this information, then must he not also be regarded as an *immanent subject* (or “group subject”) within the biosphere? And, then, don’t we need the SOT to account for such *immanent subjects*?
- How do you deal with the problem of *theodicy*? If the biosphere was created by a perfect transcendent God, then why is it pervaded by death and many other lesser imperfections? Wouldn’t acceptance of the SOT as complementary to the IDT help to answer this question along the same lines as theologians have traditionally used to answer such questions as “How can there be both human free-will and divine pre-destination?” and “Why did God leave human beings free to decide for what is evil?”

For unless we embrace the SOT and the theory of macrodevelopment as the means to transcend this seemingly interminable strife between the creationist/IDT paradigm (“that ol’ time religion”) and the neo-Darwinist paradigm (“that ‘ol time science”), we will all be condemned to “inherit the wind”!

INFORMATIONAL ANALOGS TO MACRODEVELOPMENT

Now that we have established that the self-organization paradigm is the correct *immanent teleological analog* to macrodevelopment (which, in turn, is the correct *scientific* theory of biological evolution), what *informational analog* to macrodevelopment does this suggest?

In the first place, evolutionary macrodevelopment is evidently a process of *unfolding information*, from the generic to the specific, just as is the case for individual embryonic development. Can we say anything else about this *unfolding* process?

One hypothesis is that this macrodevelopmental unfolding of biological information via nonlinear continuity-breaking bifurcations was *genetically programmed*. This is essentially what Robert F. DeHaan himself proposes:

According to the developmental perspective, the central [genetic] library was highly organized, with its information divided and subdivided into sections. Thus the phyletic germ line of each stem animal was differentiated and segregated into suites or modules of genetic programs along with their controlling regions. As a given phyletic germ line unfolded after the Cambrian explosion, it produced a lineage whose long journey through geologic time was shaped like a step-pyramid in Egypt, descending in step-wise fashion from the topmost stem animal into ever-lower, more-specific, and widening categories of lineage. That is, the control was hierarchical. The body plan of the stem animal at the top constrained the offspring in the next-lower category, the second-lower category controlled all those below it, etc. These progressively descending, more-specific steps are called taxonomic levels of lineage that help scientists classify animals and plants. The phyletic germ line continued to be differentiated and segregated and expressed in this fashion, descending ever more-specifically through classes, order, families, genera, clear down to species, at which point the last programs of the lineal germ line were completely played out. This [macrodevelopmental] process resulted in the multiplicity of species found in the present time, numbering by some estimates, from 5 million to 50 million, but which have not produced any new, higher-level organisms.

The above scenario suggests further that the phyletic germ line may have originated, perhaps as sets of highly-ordered genes, such as the Hox genes, tucked away in relatively simple, undifferentiated, Precambrian proto-animals.²⁸

While I do think that Robert F. DeHaan is *essentially* correct, I believe that he here over-stresses the role of *genetic programming* in this process. Rather, it seems to me much more likely that the nonlinear continuity-breaking bifurcations of macrodevelopment were *holistic* processes in which *cell-level epigenetic factors* and *macroscopic factors* (such as the “decisions” of biological taxa and individuals to respond to their environment in specific ways) significantly affected precisely how the biosphere’s information was “un-folded”.

The major problem with DeHaan’s view as stated is that it appears to require that *all* of the information necessary to construct *all* of the biological organisms in the biosphere for *all* time were contained within the DNA of the first “relatively simple, undifferentiated, Precambrian proto-animals”. While it is, indeed, barely possible that this huge amount of information could arise out of the quantum depths of primitive DNA, or alternatively

could arise as a result of the “unmasking” of existing DNA genes, it seems to me far more likely that this huge amount of information at least partially arose as the result of multi-millions of self-organizational “decisions” at all biological levels over millions of years being “fed back” holistically into DNA, epigenetic storage, and even into macroscopic biological storage (e.g., into macroscopic organs such as the brain).

This holistic viewpoint (a kind of “super-Lamarckism”!), as opposed to the pure-genetic-programming viewpoint, is suggested, for example, by the fact that genes and homologies don’t always coincide. As Gavin de Beer wrote in 1971: “Because homology implies community of descent from . . . a common ancestor, it might be thought that genetics would provide the key to the problem of homology. This is where the worst shock of all is encountered. . . [because] characters controlled by identical genes are not necessarily homologous . . . [and] homologous structures need not be controlled by identical genes.” De Beer concluded that “the inheritance of homologous structures from a common ancestor . . . cannot be ascribed to identity of genes.”²⁹

Other factors pointing to this kind of “super-Lamarckian” holism include: *a*) cases where different proteins are read off the *same* stretch of DNA by *frame-shifting* the reading, *b*) cases where the *alternative splicing* of messenger RNA causes the same DNA “gene” to “encode” for hundreds (or even thousands) of different proteins,³⁰ *c*) the fact that there are often far fewer genes than proteins, and *d*) the fact that homologous proteins are not, by themselves, “traits”, but only the building-blocks of “traits”.

Even with respect to the development of the individual embryo, it is now recognized that epigenetic factors are of the utmost importance, and that the embryo itself holistically “decides” such important things as the sex of the organism and which other traits the organism will take from which parent. (In other words, even the development of the individual embryo is not completely “programmed” by its genes.)

Of course, as we noted in a previous section, *most* of the nonlinear bifurcations which occur during the embryonic development of the biological individual are of the *spatial* continuity-breaking “pre-determined” variety, but this need not necessarily be true in the case of macrodevelopment.

A key evolutionary question then becomes: “To what extent are the particular nonlinear bifurcations that created the taxa within the biosphere instances of *temporal* continuity-breaking, and to what extent are they instances of *spatial* continuity-breaking only?” (This is roughly equivalent to asking, “If we were able to run the evolutionary experiment again, to what extent would the taxonomic structure be the same, and to what extent different?”) The answer to such questions is further complicated by the fact that, even though taxon-creating nonlinear bifurcations may themselves be mainly *spatial*, they may be critically influenced by other nonlinear bifurcations within the biosphere that correspond to on-the-fly internal “decisions” which *do* have an important *temporal* element. (Like all new paradigms in science, macrodevelopment raises a whole host of questions not considered under the previous paradigm.)

CONCLUSION

Hopefully this paper has succeeded in showing the value of an analogical approach to the relationship between teleology, science, and information theory. By means of this approach we have:

1. provided further strong evidence *against* the evolutionary theory of *neo-Darwinism*.
2. provided further strong evidence *for* Robert F. DeHaan's evolutionary theory of *macrodevelopment*.
3. left ample room for both an *immanent* teleological theory of the biosphere (i.e., *self-organization*) and a *transcendent* teleological theory of the biosphere (i.e., *intelligent design*), without violating the principle of methodological naturalism within science itself.

END NOTES

- ¹ Phillip L. Engle, *Far From Equilibrium* (Greensburg, Pennsylvania: Laurel Highlands Media, 2002)
- ² Dilip Kondepudi and Ilya Prigogine, *MODERN THERMODYNAMICS: From Heat Engines to Dissipative Structures* (New York: John Wiley & Sons, 1998), pp. 428-431.
- ³ Kondepudi and Prigogine, p. 430.
- ⁴ Gregoire Nicolis and Ilya Prigogine, *Exploring Complexity: An Introduction* (New York: W.H. Freeman and Company, 1989), pp. 59-60, 171-173.
- ⁵ Nicolis and Prigogine, p. 60.
- ⁶ Nicolis and Prigogine, p. 24.
- ⁷ Prigogine and Stengers, p. 166.
- ⁸ Eric Jantsch, *The Self-Organizing Universe* (Oxford: Pergamon Press, 1980), p. 49.
- ⁹ Kondepudi and Prigogine, pp. 451-2.
- ¹⁰ Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue with Nature* (Toronto: Bantam Books, 1984), p. 171.
- ¹¹ David Berlinski, "The Deniable Darwin", *Commentary*, vol. 101 no. 6 (June 1996), citing Richard Dawkins' book *The Blind Watchmaker*.
- ¹² David Berlinski, *Commentary* (September 1996): Reply to critics of his June 1996 article in *Commentary*, "The Deniable Darwin".
- ¹³ Thomas Schneider, "Evolution of Biological Information", *Nucleic Acids Research* (Summer 2000).
- ¹⁴ William A. Dembski, in *Metanexus: The Online Form on Religion and Science* <<http://www.idurc.org/americanobsession.shtml>>.
- ¹⁵ William A. Dembski, *No Free Lunch* (Lanham, Maryland: Rowman & Littlefield, 2001).
- ¹⁶ Engle, pp. 327-421.
- ¹⁷ Robert F. DeHaan, "Paradoxes in Darwinian Theory Resolved by a Theory of Macro-Development", *PSCF* 48 (September 1996): 180, "Introduction to the Phylo-Developmental Framework" (May 11, 1997) <<http://www.macrodevelopment.org/concept.html>>, and "A Brief Critique of Evolution from the Developmental Perspective" (October 7, 1997) <<http://www.macrodevelopment.org/critiq.html>>.
- ¹⁸ Robert F. DeHaan, "Paradoxes in Darwinian Theory Resolved by a Theory of Macro-Development", *PSCF* 48 (September 1996): 180.

- ¹⁹ Robert F. DeHaan, “Paradoxes in Darwinian Theory Resolved by a Theory of Macro-Development”, *PSCF* 48 (September 1996): 180.
- ²⁰ Robert F. DeHaan, “Introduction to the Phylo-Developmental Framework” (May 11, 1997) <[http:// www.macrodevelopment.org/ concept.html](http://www.macrodevelopment.org/concept.html)>.
- ²¹ Robert F. DeHaan, “Introduction to the Phylo-Developmental Framework” (May 11, 1997) <[http:// www.macrodevelopment.org/ concept.html](http://www.macrodevelopment.org/concept.html)>, citing Niles Eldredge, *Evolutionary Macrodynamics* (New York: McGraw, 1989), p. 4.
- ²² John Whitfield, “Magical Numbers in Nature” (an interview with Ian Stewart), *Nature: Science Update* (October 28, 2001) <[http:// www.nature.com/ nsu/011018/ 011018-3.html](http://www.nature.com/nsu/011018/011018-3.html)>.
- ²³ Phillip E. Johnson, “God and Evolution: An Exchange”, *First Things* (June 1993) <[http:// / www.firstthings.com/ ftissues/ ft9306/ Johnson.html](http://www.firstthings.com/ftissues/ft9306/Johnson.html)>.
- ²⁴ Robert F. DeHaan, personal communication to the author via email on November 27, 2000.
- ²⁵ Engle, pp. 327-421.
- ²⁶ Stephen C. Meyer, “DNA and Other Designs”, *First Things* 102:30-38 (April 2000).
- ²⁷ Phillip E. Johnson, “Dembski and Kauffman Square off in New Mexico”, *Weekly Wedge Update*, November 19, 2001 <[http:// www.arn.org/ docs/ pjweekly/ pj_ weekly_ 011119.htm](http://www.arn.org/docs/pjweekly/pj_weekly_011119.htm)>.
- ²⁸ Robert F. DeHaan, “Introduction to the Phylo-Developmental Framework” (May 11, 1997) <[http:// www.macrodevelopment.org/ concept.html](http://www.macrodevelopment.org/concept.html)>.
- ²⁹ Gavin de Beer, *Homology: An Unsolved Problem* (London: Oxford University Press, 1971), pp. 15-16, as cited by Jonathan Wells, *Icons of Evolution* (Washington D.C.: Regnery Publishing Inc., 2000), p. 73.
- ³⁰ Barry Commoner, “UNRAVELING THE DNA MYTH: The Spurious Foundation of Genetic Engineering”, *Harper’s Magazine* (February 2002).