scholarship, which impresses me as a good example of Polanyi's notion of "personal knowledge."

This book is worthy of being read, because it is well-written, the chapter notes, bibliography, and index are edifying, and specialists and nonspecialists will find the content satisfying. On the balance, *The User Illusion* embodies an expression that Einstein reportedly used during his Princeton years whenever he was working on a particularly difficult problem, "I will a little think."

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Lamarck's Signature by Edward J. Steele, Robyn A. Lindley, and Robert V. Blanden. Reading, MA: Perseus Books, 1998. xxi + 286 pp. $25.00 (c). ISBN 0-7382-0014-X.

Epigenetic Inheritance and Evolution by Eva Jablonka and Marion J. Lamb. New York: Oxford University Press, 1995, x + 346 pp., $60.00, (c). ISBN 0-19-854062-0.

The incredible richness of the biosphere challenges us with obvious questions: What is the origin of diversity among plants and animals? Are natural kinds static, or do they change over geological time? What are the forces causing these changes, and are they directed toward specific ends? Is there any drive toward increasing complexity, and if so, what is the relationship of this process to entropy? What is the interplay between heredity, embryonic development, and ecology?

A theory that addresses these issues is needed as a cornerstone of biology. We now know a significant amount about the processes at work during the morphogenetic events that turn a fertilized egg into an embryo and then an adult. In large part, these processes are directed by the genome—information that is instantiated by patterns within DNA molecules. This information is passed from parent to offspring and carries instructions telling molecular machines how to assemble and modify a growing embryo, as well as instructions for building the machines themselves. It is now appreciated that the genome is not simply "beads on a string" of DNA; functionally, it consists of logic elements, subroutine modules, addresses for information retrieval and modification, error-correction mechanisms, hierarchical organization, *etc.* (see Shapiro, 1991).

The inheritance of acquired characteristics theory was a natural way to attempt to explain cases of marvelous adaptation of organisms to features of their environment. This idea is most often associated with Lamarck, though it had adherents both before him and after him. Moreover, Darwin himself thought that inheritance of acquired characteristics did occur. This theory has the benefit of providing easily believable explanations. For example, the camel has rough pads on its knees because constant kneeling in gritty sand causes a thickening of the skin in that area. Unfortunately, in this most simplistic form, this theory faces a number of problems. For example, it would seem that most changes acquired by an organism within its lifetime are due to injury, disease, and age and are not beneficial to pass on to offspring. Likewise, it is often pointed out that thousands of years of circumcision have not produced a tendency for males to be born without foreskins. "Weismann's Barrier" provides a "genetic chastity belt around the reproductive organs" (*Lamarck's Signature,* p. 165). In most animals, offspring arise from a very small subset of the adult organism's cells—the germ line, whose cells are segregated long before adulthood, so changes occurring to somatic body cells are not passed on.

It is possible to attempt to circumvent such objections. For example, *Epigenetic Inheritance and Evolution* discusses interesting complications such as the possibility of existing germ cells being subject to selection and competition; these processes may well be affected by environmental factors, simulating environmental inheritance when applied over the endogenous variation among germ cells. However, there is a much more basic reason why large-scale morphological changes wrought on the adult body cannot be passed on to offspring.

The crucial factor is embryonic development. It is now known that embryos arise as the result of the complex interactions of chemicals generated in response to information contained in the DNA. The genetic material does not appear to contain descriptions of the outcomes of embryogenesis. The existence of reverse transcription (turning mRNA back into DNA), and even the possibility of reverse translation (turning a protein into mRNA), is simply not enough. The process of development is unidirectional; the laws of biochemistry are what drive the generation of form (such as a limb or nervous system) from basic ingredients such as proteins. There is no way to reverse the process and compute how to adjust every protein, including structural ingredients as well as controlling machinery, to result in a particular feature, such as a longer neck. The process of generation of fractal images shares this property. Given a simple mathematical function such as $z = z^2 + c$, it is easy to produce fractal images of great complexity and beauty. The nature of chaos theory makes it impossible to reverse the process. Given a different image, it is simply not possible to know how to alter the function to produce the desired image. The same is true of embryonic development.

However, there are limited cases in which inheritance of acquired characters does appear to occur; these are discussed in fascinating detail in *Epigenetic Inheritance and Evolution*. For example, plants do not all have a germ line/soma distinction. In plants where a new organism can regenerate from any part of the adult, changes made to adult body parts can indeed become part of the offspring. Likewise, protozoa (single-cell organisms) can pass on altered features of their cytoskeleton, for example, because they reproduce by fission of the adult organism. Bacteria can acquire genetic material from the environment (in the form of "minichromosomes" such as episomes), and because these also reproduce by fission of the adult, such changes can become a permanent part of the reproducing line.

Given the powerful reasons why Lamarckian mechanisms are unlikely to play a role in large-scale morphological change, what alternatives remain? The Darwinian theory is a conclusion drawn from three facts, all of which were known long before Darwin's day. These basic axioms are as follows: (a) Offspring resemble their parents more than they resemble unrelated individuals (equal traits are hereditary), (b) he transmission of characters from parents to offspring occurs with high but imperfect fidelity, and (c) resources (such as food, mates, territory, *etc.*) are limiting because of the exponential growth of populations during times of plenty. The genius of Darwin was to realize (and support by painstaking observation) the claim that these three facts, when joined together, form a powerful system for explaining evolutionary change. Because of the intense competition for limited resources, even small advantages lead to increased chances for survival; thus, beneficial errors in hereditary transmission will accumulate and eventually dominate the population over geological timescales.

This basic scheme, when carried over a sufficient number of individuals, over sufficiently great timescales, is an immensely powerful way to leverage random changes into adaptive results. This algorithm is so generally useful that it has been applied to explain the fine-tuning of everything from thoughts and concepts in human culture (Dawkins, 1976) to basic physical laws of the universe (Smolin, 1997) to computer programs that solve problems for which we have no algorithmic solution (Koza, 1992). In biology, as well as in applications of genetic strategies for other sciences, the basic issue is to define the unit of selection (genes versus organisms; *e.g.*, Dawkins, 1982) and the fitness function, a way of assessing the quality of individuals.

It should be noted that the three basic axioms of modern evolutionary theory are not controversial. What may be questioned, although it usually isn't, is the issue of whether they are sufficient to explain the incredible richness of the biosphere. The success of mimicking the Darwinian strategy to design computer programs (known as Genetic Programming, Holland, 1992) suggests that our intuition far underestimates the creative power of this process. At the same time, progress in the field of Genetic Algorithms research seems to have slowed considerably on the hard problems, and it remains an open question as to whether a closer look at the mechanisms of development (the layer between genotype and phenotype) will be sufficient to successfully apply evolutionary strategies to those difficult problems.

The idea that random changes can be harnessed by any mechanism to result in everything from viruses to human beings is repugnant to some, and a well-known group of antievolutionists exists. They have argued that physical processes in and of themselves are not sufficient to result in the appearance of complex biological organisms. It is important to note that Lamarckian inheritance is of no use whatsoever to religious fundamentalist or dualist thinkers in arguing against the sufficiency of material evolution. A theory of environmentally caused changes that are inherited is just as mechanistic as neo-Darwinism; it is simply another way to explain adaptation without recourse to a grand design or creator. Of course, some will argue at this point that it is God who directs which somatic changes are carried into the genome. This move is useless, as then one might just as well posit that God controls what mutations occur in DNA, to later be subject to Darwinian selection.

These are all interesting issues and are dealt with in these two volumes. *Epigenetic Inheritance and Evolution* is an excellent book for the amateur or professional biologist. It begins by reminding the reader that heredity is not transmission of characters but of instructions: A pure line of animals has identical genetic instructions, but the manifestation of their characteristics can be influenced environmentally. This book is packed with interesting special cases in which Lamarckian-like inheritance occurs. It covers inheritance systems other than the genome (epigenetic inheritance systems), such as episomes, phages, retroviruses, mitochondria, cytoskeleton (cilia, basal bodies, entrioles), chromatin marking, methylation, X-inactivation, mobile elements in DNA, *etc.,* and discusses in excellent detail their role in sex, evolution, multicellularity, speciation, meiotic drive, hybrid inviability, *etc.* It has enough detail to satisfy, and it makes great reading for anyone who is interested in the details of real biology. Also included are viral shuttling of genetic info between organisms (horizontal inheritance), imprinting, parental age effects, and maternal control of gene expression. Issues such as segregation of germ line in various organisms and interactions between epigenetic systems and the genome are covered as well. Despite these fascinating examples of alternative types of inheritance, the authors point out early on (p. 20) that somatic changes are not put back into the germ line.

Lamarck's Signature is also a very good read, aimed at more of a layperson audience. It is part of the *Frontiers of Science* series (edited by Paul Davies)—a set that contains several other excellent books. This book doesn't cover as many examples of nonstandard inheritance as *Epigenetic Inheritance and Evolution.* The first six chapters are a good introduction to basic evolution and Lamarckism, molecular and cell biology, and immunology; they cover the basics in good detail: DNA, RNA, transcription, editing, viruses, recombination, reverse transcription, enzymes, *etc.* Only the last two chapters are about Lamarckism, and the first few set up the background.

Lamarck's Signature focuses on the idea that the immune system instantiates an example of a Lamarckian inheritance mechanism. A cornerstone of the book is the fact that the immune system is able to specifically react to a practically infinite number of antigens, which are not known in advance. It does this by a selectionist scheme, whereby specific pieces of DNA are randomly mutated and those cells containing mutations, which allow them to bind antigens effectively, proliferate. The basic idea of this book is that DNA mutation is induced within a subset of lymphocytes as an attempt to further optimize the binding of those molecules to the antigen. This in itself is an example of the environment's effects on changes in DNA (even though the mutation events themselves are still random). Moreover, by the action of reverse transcriptase (an enzyme, provided by endogenous retroviruses, that turns mRNA back into DNA) and homologous recombination within germ cells, such mutations can be inserted into the germ line and become inherited. The authors summarize, "Rapid random mutation involving the replacement of the original DNA sequence coupled to selection for a better one (encoding an antigen-binding site with higher affinity than the original antibody) effectively results in the appearance of 'directed mutation,' the complete antithesis of random mutation" (p. 162).

The two books complement each other nicely and are recommended for anyone who wants a thorough, professional, well thought out discussion of often neglected aspects of biological inheritance. *Epigenetic Inheritance and Evolution* is more technical, containing lots of in-depth examples and references. *Lamarck's Signature* is probably accessible to a wider audience; it has a very good introduction to relevant issues, but expert readers will want to skip to the last few chapters, which focus on Lamarckian inheritance in the immune system.

The word Lamarckian tends to arouse strong feelings. It should be noted that one might pick up either book expecting revolutionary models of the emergence of complex animal forms by non-Darwinian means. If so, one would be disappointed. Upon reading both books, it becomes clear that there are lots of examples in biology of simple, single-cell systems (and some plants) where inheritance of acquired characters does indeed occur, and there are lots of complex effects in higher animals where inheritance of acquired characters is mimicked by other processes. What is not found in these books (and nowhere else that I am aware of) is any evidence for the truly controversial claim of Lamarckism—that changes occurring to the adult bodies of organisms can be transmitted to offspring in such a way as to make them better adapted to their environments.

The bottom line is that all of the controversy and excitement regarding Lamarckism and its "challenge to Darwinian orthodoxy" is not only about environmental influences on the genome—we know these exist—and the idea that stress or other environmental inputs can affect mutation rates, *etc.,* isn't very frightening or damaging to the conventional paradigm. The truly threatening idea about Lamarckism is the question of teleology: Can the environment direct changes that are beneficial to the organism? Mutation may be nonrandom with respect to location (hotspots in the DNA, *etc.*), but it seems to be always random with respect to adaptive advantage. Lamarckian inheritance is exceptionally exciting if and only if it can actually help to explain the origin and changes in major aspects of morphology, as well as the exquisite machinery of the cell. Although the importance of Darwinian models of evolution is incontrovertible, deep and interesting challenges remain, for this and other theories of life (Behe, 1996; Denton, 1986; Margulis, 1998).

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Authentic Knowing: The Convergence of Science and Spiritual Aspiration by Imants Baruss. Purdue University Press, 1996. 228 pp. $14.95 (paper), $32.00 (cloth). ISBN I-55753-085-8.

Many of us believe that the signal task of human existence is to achieve a better understanding of who and why we are. Although the nature of such efforts has varied throughout history, in the past 400 years, they have consistently taken shape along a continuum defined by the polarities of religion and science. This admirably honest book attempts to harmonize these disparate elements into a common theme of man's efforts to define his place within the universe.

Baruss, a professor of psychology, contends that both science and spirituality express a need for "authentic knowing," a concept derived from Heidegger's *Eigentlichkeit*. The author summarizes the concept of authenticity as "the effort to act on the basis of our own understanding." He expands on this idea in a concentrated foray through classical and quantum physics. In so doing, he draws attention to our tendency to compartmentalize scientific and religious beliefs such that they apply little to our everyday actions and