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BOOK REVIEW

A provocative view of evolution in the genomic age

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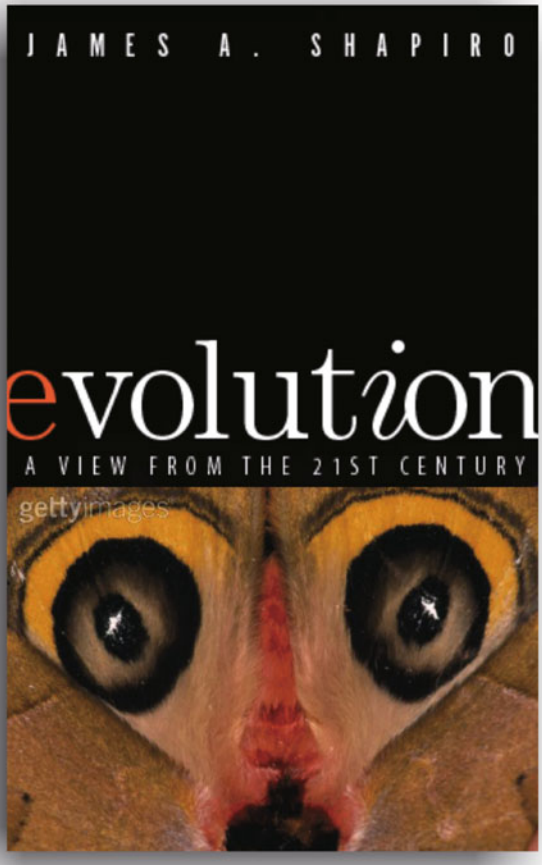
James A. Shapiro's new book "*Evolution: A View from the 21st Century*" stands out among various semi-popular books on evolution by presenting much new information gathered from recent developments in molecular genetics and genomic studies. The book uses bold metaphoric language likely to resonate with non-professional readers to advocate an informational and genomic-based approach for understanding evolution, and criticizes the mutation and selection based conventional evolutionary approach as canonized in the Modern Synthesis developed in the second half of the 20th century.

Following a brief note on how to read the book and how to use the available on-line materials for readers with different backgrounds, the book starts with a well-written introduction emphasizing the need for "a fresh look at the basics of evolution in the new century." Subsequent presentations are grouped under four major headings: Part I "Sensing, Signaling and Decision-making in Cell Reproduction," Part II "The Genome as a Read-Write (RW) Storage System," Part III "Evolutionary Lessons from Molecular Genetics and Genome Sequencing," and Part IV "A New Conceptual Basis for Evolutionary Research in the 21st Century."

In a style that tries to strike a balance for both professional biologists and interested non-professionals, the book states that conventional evolutionary theory has become outdated, and that fundamental evolutionary processes cannot be explained by natural selection or the accidental nature of mutations. The book proposes that living organisms are "self-modifying beings" and that living cells have the ability to adapt actively to changing environments by manipulating and restructuring the DNA molecules.

Among the core notions of the book, the author proposes that living organisms actively conduct "natural genetic engineering" to adapt to the environment, and that the genome is a read-write (RW) information storage system instead of the conventional read-only memory (ROM) model under which the genome is shielded from environmental influences and subject only to random mutational changes. By "natural genetic engineering," the author refers to the ability of cells to modify its genomic structure by cutting and splicing DNA molecules into novel sequence arrangements. The author uses examples such as cellular repair, mobile



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genetic elements, and cellular information processing networks to show that cells possess the ability to sense the environment and change their genomes, thereby producing novel features important for the evolutionary processes. The author points out that purely DNA-based explanations are insufficient to explain modifications of cell structures, genome-independent heredity of the cell cortex, and transmission of "epigenetic information" contained in complexes of DNA, RNA and protein. The author also cites endosymbiosis, lateral transfer, and genomic structural reorganization as examples to show that these phenomena cannot be explained by traditional evolutionary theory. The author maintains that the key question of evolution in the new century is how complex new capacities arose in the course of evolution and contributed to the ability of organisms to survive, proliferate, diversify, and reorganize their environment. The author declares that the concept of living organisms as self-modifying beings coincides with the shift in biology from a mechanistic view to an informatic view of biological processes.

Out of a total of 253 plus pages, the extensive references (1162 in number), the glossary and the index take up 105 pages. The text portion of the book takes up 145 pages, making the main text of manageable length and less intimidating in terms of bulk or volume size. The glossary is especially useful and convenient for non-professional readers, and defines relevant terms used in the book, from Acetyl coenzyme A and adaptive immunity to *Wnt* signaling molecule and zygote. The impressive list of references is not in alphabetical order, making it difficult to see at a glance whose works are cited and whose works are omitted. However, the book is amply complemented by supplementary information at the publisher's site (www.ftpress.com/shapiro), designed to help serious readers to delve into more details but also to acquaint non-professional readers with useful essential background. The electronic URL links in the on-line resources (Appendixes, Table References, References, Extra References, Suggested Readings for Non-Professionals) prove to be very handy for readers to access the abstracts or even full text articles of many references. The book itself does not contain any diagrams (though on-line in-depth materials do), a less-than-ideal situation especially in view of the need of non-professional readers who may find figures useful for a better understanding of the text.

The author has earned the respect of the scientific community for its pioneering work in mobile genetic elements in bacteria and related fields, but has also been known as an outspoken critic of "orthodox" Darwinian evolutionary theory as well as the Central Dogma of modern biology. The author claims that cells integrate different natural genetic engineering abilities into "a highly targeted and well-regulated series of changes with a clear adaptive benefit." The author believes that "the intelligent application" of these molecular mechanisms can be compared to the way human engineers work. "Although they may go through many trial-and-error steps, human engineers do not work blindly. They are trying to accomplish defined functional goals. Can such function-oriented capacities be attributed to cells? Is this not the kind of teleological thinking that scientists have been taught to avoid at all costs? The answer to both questions is yes [p. 137]."

If this is pure metaphoric language designed to bring the message to a wider readership, the author probably should make this fact clear, so that words such as "adaptive benefit," "intelligent utilization" and "genomes as intelligent problem solving systems" do not get conflated in the mind of non-professional readers. One way or another, the usage of these words is distantly reminiscent of Aristotelian teleology or Kantian's concept of nature "as a system of ends." Philosophical connotations apart, scientific hypotheses need to be precisely stated or expressed verbally, graphically or mathematically, in order to be testable. One wonders to what extent the main ideas presented in this book through the medium of metaphoric language can be actually used to clarify key concepts in evolutionary studies or to generate specific new research agenda.

Mindful of the "philosophical" opposition on the part of "mainstream biologists, and evolutionists in particular," the author maintains that "ideas of cell cognition, decision-making, and goal-oriented function are within contemporary biological perspectives," and that the "natural genetic engineering concept is subject to empirical investigations [p.138]." However, the "bottom up" and "top down" approaches suggested by the author [pp. 137-138] sound like general directions in which to look for future corroboration rather than specific strategies to design rigorous tests against competing hypotheses.

The provocative view of evolution, combined with the summary of much interesting information bundled in a handy format (the main text of the book being only 147 page long), makes this book worth reading by evolutionary biologists, professors teaching evolution, advanced students as well as general readers eager to explore opposing views in evolution-related debates. Like a sip of old wine slowly releasing its full battery of aromas, the book may leave different tastes for different readers at different times.

The book presents the author's unique views on important questions such as how cells work and what are the engineering and operating principles of living organisms. Clarification of these important questions will impact the theoretical and conceptual frameworks of evolutionary biology that serve to guide the design, conduction and interpretation of current and future biological research. For all its virtues and shortcomings, Shapiro's succinct book may serve as a wake-up call for practicing evolutionary biologists to pay more attention to advances and developments in molecular genetics and genomic studies and to consider the

implications of these advances for the theoretical framework of evolution in the 21st century.

My main criticism of the book concerns its neglect to mention the in-progress work within the ranks of mainstream evolutionary biologists to use recent advances in many different fields to scrutinize, rectify and/or extend various components of the Modern Synthesis. Many evolutionary scientists have pointed out gaps, limitations or inconsistencies in Modern Synthesis from the vantage point of modern biological research, especially areas such as evolutionary-developmental biology (evo-devo), molecular genetics and genome studies. Interested readers are encouraged to read both Shapiro's book and Pigliucci and Muller's "*Evolution – The Extended Synthesis*." Criticisms of the Modern Synthesis developed half a century ago only attest to the vigor and strength of scientific theories, and all readers will benefit by seeing how scientists can take different approaches when dealing with major theoretical issues encompassing almost all areas of biological study.