TELEVISION: EVOLUTION

Everyday Impacts of a Most Influential Theory

Timothy H. Goldsmith

If I were to give a prize for the single best idea anybody ever had, I'd give it to Darwin for the idea of natural selection. Ahead of Newton, ahead of Einstein, because his idea unites the two most disparate features of our universe: the world of purposeless, meaningless matter in motion on the one side, and the world of meaning and purpose and design on the other. He understood that what he was proposing was a truly revolutionary idea.

These words are spoken early in the television production *Evolution*, which airs on the Public Broadcasting System in the United States next week. With them, the philosopher Daniel Dennett captures eloquently the power and the beauty of evolutionary theory and at the same time identifies the intellectual dilemma faced by those who lodge their understanding of nature in a literal reading of scriptures. In view of the guerrilla warfare over the teaching of evolution that is taking place in school boards and state legislatures around the United States, the appearance of this series is both timely and useful.

Evolution
WGBH Educational Foundation, Boston, and Clear Blue Sky Productions, Seattle, WA. On PBS, evenings, 24 to 27 September 2001.

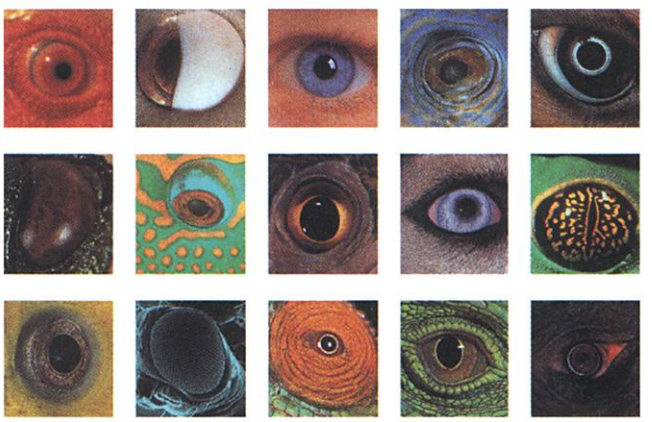
Evolution
The Triumph of an Idea
by Carl Zimmer
HarperCollins, New York, 2001. 384 pp. $40, C$59.95. ISBN 0-06-019906-7.

Many of the arguments presented by the anti-evolutionists as "evidence"—those that go beyond the desire to see science accommodate the unobservable and the unmeasurable—are hollow echoes from the 19th century. For example, the incompleteness of the fossil record and the alleged perfection of the human eye are regularly trundled out as if understanding of evolution has remained frozen since the publication of *The Origin of Species* in 1859. For viewers interested in the history of ideas and the scope of contemporary evolutionary theory, the seven episodes of PBS's *Evolution* provide diverse and fascinating examples of how rapidly our understanding of this important natural process is growing. For example, recent discoveries of transitional forms in the evolution of whales illustrate how paleontology continues to provide confirmation of the Darwinian concept of descent with modification. (Early whales are the subject of a Report by Gingerich *et al.* on page 2239 of this issue and of the accompanying Perspective by Rose on page 2216.)

Since Darwin's day the catalog of simple eyes of invertebrates has expanded greatly. These are not transitional forms to the vertebrate eye, but they show that eyes of varying degrees of complexity have arisen scores of times. Recent computer models validate how easy this is. Starting with a small sheet of light-sensitive cells and conservative assumptions about incremental changes, optically respectable eyes with spherical lenses can evolve in a few hundred thousand generations, ample time for evolution. At the molecular level, the recent research on a family of genes that control the expression of still other genes during the embryological development of animals as different as mammals and insects reveals an underlying order to diverse body plans that was unanticipated a generation ago. Although much remains to be discovered, neither macroevolution nor the Cambrian explosion are as mysterious as the anti-evolutionists would have us believe.

The series begins with a segment on Darwin himself. In this episode, the writers have used Darwin's older brother Erasmus as a kind of foil: a contrast to Charles's caution and a vehicle for revealing the development of his ideas about natural selection. This approach works well, and the resulting picture of the naturalist is accurate in its important details. Those familiar with the Richmond portrait of Darwin as a young man may feel that on the screen he appears a bit hefty, and they may be disconcerted by his failure to age during the following 30 years. But I quibble.

Subsequent episodes share the interrelations of organisms as an overarching theme. One explores the significance of extinction. Perhaps 99% of all species that have ever existed have gone extinct, which is hardly evidence for intelligent design. The mean lifetime of a species is estimated to be 4 million years, and the demise of species during bouts of mass extinction creates opportunities for the adaptive radiation of surviving organisms. The final message on extinctions is a reminder that human behavior—habitat destruction, pollution, climate change, poaching, and the introduction (accidental or deliberate) of species into new environments—is causing extinctions at an alarming rate. In our success, we have become the ultimate "weed species."



A colorful glimpse at the power of evolution. Despite the striking differences among them, the 24 eyes depicted on the cover of Zimmer's book offer only a taxonomically restricted sample of the range of forms that evolution has produced; all but two (both present in this subsample) are from vertebrates.

The program on evolutionary arms races demonstrates that most prevalent forces driving evolution usually come not from the physical environment but from other organisms. As an adaptation to minimize predation, the rough-skinned newt has gained the ability to secrete enough tetrodotoxin to kill several humans. In turn, one predator, the red-sided garter snake, has evolved a genetic resistance to the newt's poison. But even for these snakes, eating such newts has its price because, although the snakes are not killed, they become sluggish and more vulnerable to their own predators. Such examples show viewers that evolutionary adaptations are frequently compromised. However, the interplay between pairs of species is much easier to understand than the network of interactions that characterize an ecosystem. The same episode explores the consequences of the fact that human inventiveness in discovering antibiotics has been accompanied by the folly of indiscriminate use. Subjected to such intensive natural selection, a variety of infectious organisms are evolving drug resistance faster than the pharmaceutical industry can re-

The author is in the Department of Molecular, Cellular, and Developmental Biology, Yale University, New Haven, CT 06520, USA. E-mail: timothy.goldsmith@yale.edu

CREDIT: COURTESY HARPERCOLLINS

spond. As the program illustrates vividly, Russian prisons are an incubator for forms of the tuberculosis bacillus that could bring us the next pandemic. But to provide perspective, leaf-cutter ants have been agriculturists and using antibiotics for 50 million years without getting into this kind of trouble.

Other programs explore contemporary understanding of why organisms come in two sexes, ideas about the evolution of the human mind, and the new field of evolutionary psychology. Although even human behavior has been shaped by evolution in important ways, cultural evolution, lubricated by language, outpaces natural selection. Consequently, in the realm of culture—of ideas—"for the future of humankind, evolution may be no more than what we make of it." But as we continue to live in a world of organisms shaped by biological evolution, we need to understand better the consequences of our actions lest "what we make of it" is a complete mess.

Scientists who have ignored the political efforts to undermine the teaching of biology should be sure to view the final episode. "What about God?" addresses the politics of science education with unusual candor. Some of the scenes of conflicted high school students and their teachers are particularly compelling. At one level, the adolescents stir a measure of admiration for spunk as they urge the school board to harmonize biology with the different picture of the world they receive at home. But the deeper message, clearly understood by their anguished teachers, is that for these kids, at this age, it is close to impossible to teach them how science is different from faith. The scenes from Wheaton College, an interdenominational Christian institution, show the struggle unfolding with students who are a few years older. For some, hearing about evolution from a scientist who professes a strong religious faith can have more impact than all the evidence in the textbooks.

My one criticism of this coverage is that it may leave the impression that anti-evolutionists are all young-earth creationists. Such is not the case; anti-evolutionists occupy a broad theological spectrum and they are not all Christians. Moreover, as the courts have seen through the sham of "creation science," other "alternatives" to evolution have emerged. The latest, masquerading as cutting-edge science, is another echo from the past called "intelligent design theory." It asserts that the molecular machinery of cells is "irreducibly complex" and therefore requires a designer (unidentified). Hardly a theory in any useful meaning of the word, it is another example of what Richard Dawkins has called an argument from personal incredulity.

This PBS series may not change many committed minds, but viewers who approach it with curiosity will be rewarded by some intriguing views of evolution at work. For those who want to dig deeper, there is a richly illustrated and lucidly written companion book by Carl Zimmer.

BOOKS: NEUROSCIENCE

Beautiful Transfer of Information

Mary B. Kennedy

Information processing in the brain depends critically on the appropriate electrochemical transmission of signals from one neuron to another at synapses. Rapid progress in molecular and cellular biology over the last decade has fueled similar progress in our understanding of synaptic transmission; indeed our view of synapses in the brain has been transformed. In mid-1999, the Howard Hughes Medical Institute (HHMI) hosted a workshop on synapses; that gathering gave rise to the idea of a monograph summarizing recent progress. W. Maxwell Cowan, Thomas C. Südhof, and Charles F. Stevens (the recently retired HHMI chief scientific officer and two HHMI investigators) edited the resulting hefty volume. *Synapses* is comprehensive in its coverage. The quality of the writing and of the numerous beautiful color figures is excellent. Thus, the volume is a suitable textbook for an advanced graduate course as well as an authoritative reference for practicing neurobiologists.

Synapses
W. Maxwell Cowan, Thomas C. Südhof, and Charles F. Stevens, Eds.
Johns Hopkins University Press, Baltimore, 2000. 783 pp. $69.95, £48. ISBN 0-8018-6498-4.

Three introductory chapters set the remaining contributions clearly into context. To begin, Cowan and Eric Kandel offer an engaging history of the study of synaptic transmission from the first hints of its existence in 1791 through the 1970s. They choose to recount this history in light of two major controversies. The first revolved around the question, "Are neurons discrete cells or connected in a syncytium?" It was fueled by the limits of resolution of microscopy prior to the invention of the electron microscope. The denouement of the second, "Is synaptic transmission electrical or chemical?" also required better techniques. However, the answer, that both are important, shows that personal biases also stood in the way of a clear outcome. Controversy sometimes restrains progress in science instead of encouraging it. The chapter reveals another aspect of scientific sociology as well. The elegant studies of familiar early masters are recounted in detail, but many women who made crucial contributions are not mentioned. For example, the authors mention explicitly the description by Katz *et al.* of the postsynaptic membrane folds at the neuromuscular junction, "a region now known to be densely packed with [acetylcholine] receptors." We know about the packing of acetylcholine receptors at the top of the folds from the stunning work of Miriam Salpeter who invented quantitative electron microscope autoradiography to make this discovery, yet she is not cited. And the account of critical research on the *N*-methyl-D-aspartate channel names Mark Mayer, Gary Westbrook, and Philippe Ascher but omits Ascher's coauthor Linda Nowak. This informative chapter is a delight to read, but it reveals clearly how women's contributions tend to disappear.

The second chapter offers a richly illustrated account of the varied structures of synapses revealed in the electron microscope. It underscores the principle of cell biology that "structure underlies function." The authors raise an important question for the future: "What are the differing functions of brain synapses with obvious, if subtle, structural differences?" The third introductory chapter provides a lucid description of the basics of synaptic electrophysiology, emphasizing synapses in the central nervous system.

Chapters Four through Eight focus on the molecular organization and mechanisms governing the functions of the presynaptic terminal, the synaptic cleft, and the postsynaptic signaling apparatus.The chapters furnish elegant summaries of detailed working models of each organelle, demonstrating how the revolution in molecular biology has made its mark in neuroscience. At the same time, the authors point out the uncertainties in the models and, therefore, the most important questions remaining to be answered.

Five chapters cover the fascinating plastic properties of brain synapses. They recount the intense efforts to understand the baroque mechanisms by which the strengths of individual synapses are set and the roles of synaptic plasticity in brain development and memory storage. In addition to results from the molecular revolution, an explosion of new techniques in electrophysiology and fluorescence microscopy, driven by advances in materials science and the growth of computer power, have provided a wealth of new information in a relatively short time.

The volume's last two chapters point most strongly toward the future. Sol Snyder (with his charming iconoclastic style) and Christo-

The author is in the Division of Biology, California Institute of Technology, Pasadena, CA 91125, USA. E-mail: kennedym@its.caltech.edu