

usually combined with the word for ancestral) have more of the connotation of teaching—they are also used, for example, in references to teacher and professor. They reveal a semantic frame differing greatly from that familiar to most westerners. I can't help reflecting that Kauffman would have an easier time getting his ideas adopted by religious people outside the three Abrahamic faiths. But these people will likely say that they already have such a religion and do not see why they need anything else. Bringing science and religion together globally in the way that Kauffman wishes is not going to be easy—as other ecumenical movements have repeatedly found—but it is necessary.

References

1. S. A. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (Oxford Univ. Press, New York, 1993).
2. S. A. Kauffman, *At Home in the Universe: The Search for Laws of Self-Organization and Complexity* (Oxford Univ. Press, New York, 1995).
3. S. A. Kauffman, *Investigations* (Oxford Univ. Press, New York, 2000).

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MICROBIOLOGY

Learning Much from a Bug's Life

Daniel J. Rankin

Here too are the dreaming landscapes, lunar, derelict. Here too are the masses, tillers of the soil.

So begins “In the Microscope” by the immunologist and poet Miroslav Holub (*1*). Through his microscope's lens, Holub saw “cells, fighters who lay down their lives for a song” and heard “murmuring, the revolt of immense estates.” In short, his poem reminds us that all of the ingredients of a good Shakespearean play can be found in the microscopic world.

Holub was writing under political oppression in communist Czechoslovakia, and he often took a dark view of the world around him. In *Microcosm: E. coli and the New Science of Life*, Carl Zimmer, a Connecticut-based science writer, paints a rosier picture of his focal organism. The “fighters who lay

down their lives” in his book come under the scientific name *Escherichia coli*, an organism that has achieved notoriety thanks to various outbreaks of harmful strains in recent years. However, leafing through the pages of this gripping book, one cannot help but feel pangs of sympathy for this delightful little creature.

Ranging widely across nearly all of contemporary biology, Zimmer presents *E. coli* as a basis from which one can gain a better understanding of almost every facet of biotic life. He moves from the inner workings of the cell, through the social life of *E. coli*, to, in the very last chapter, outer space (where he uses *E. coli* to ask whether life exists on other planets and, if so, what such life may look like).

First impressions never seem to help when looking at microbes. For a long time, scientists did not believe microbes could have sex. The late Joshua Lederberg and colleagues discovered bacterial conjugation, showing that *E. coli* could exchange genes through direct contact with other cells. Not only can *E. coli* have sex but, like higher organisms, it has a rather complex social life. For example, when food is limited, members of a population can signal to one another to enter a stationary phase. The phase improves the chances that at least a few of the members will survive, effectively relying on safety in numbers. However, life is not always so friendly for the star of Zimmer's book. In addition to cooperation, there is also strife in the bacterial world. To compete

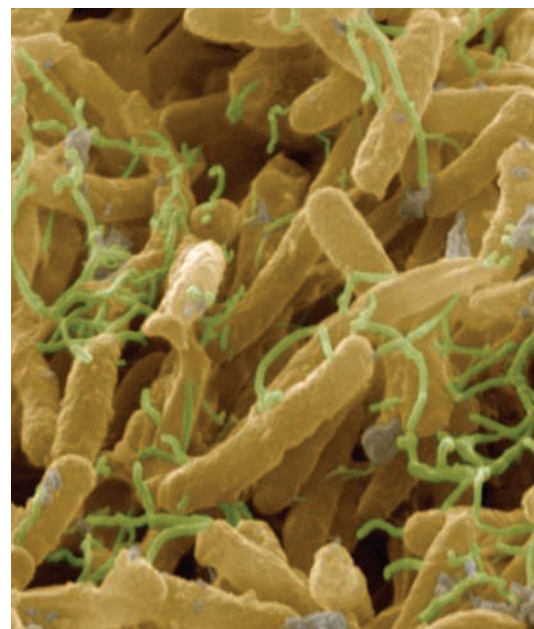
with other species, or even its own kind, *E. coli* can produce chemical weapons, in the form of antibiotics.

Evolution is never far away from the author's mind. He quotes Charles Darwin's comment that “natural selection will

always act with extreme slowness, I fully admit” (*2*). In fact, Darwin would have marveled at *E. coli* and at researchers' ability to use it to confirm many predictions of his theory. Countless laboratory experiments have demonstrated adaptation in the species on time scales short enough for us to observe, and it has played a role in discrediting Lamarckian inheritance.

E. coli has even been presented in defense of evolution itself. The bacterial flagellum, which is rotated to propel the organism, has recently featured in the controversy surround-

ing intelligent design. Advocates of intelligent design often offer the flagellum as an example of a structure too complex to have evolved through natural selection. Michael Behe testified to that effect for the defense when parents in Dover, Pennsylvania, sued the local school district over the teaching of intelligent design in science classes (*3*). The plaintiff's attorneys countered with scientists who demonstrated how it was possible for the flagellum to have evolved from useful, intermediate structures, even if those structures did not function in



***E. coli* cluster.** This rod-shaped bacteria was first isolated in 1885, from the diapers of healthy babies, by the German pediatrician Theodor Escherich, who noted the microbe's ability to produce a “massive, luxurious growth.”

bacterial locomotion. Complicated structures such as flagella could therefore have evolved through small evolutionary steps, thus discrediting a central argument used against evolutionary theory.

A large part of the book discusses biotechnology, which owes a lot to *E. coli*. The early days of genetic engineering were fraught with political problems, with many warning of potentially harmful effects for society and the ethical implications of playing God. However, once the benefits for society as a whole became apparent, the science was allowed to proceed. By inserting animal genes into *E. coli*, strains were developed to fill tanks that now pump out gallons of insulin and other drugs every day. As Zimmer notes, *E. coli* genes are now being inserted into animals. For example, researchers have transferred to pigs genes that allow *E. coli* to break down phosphate-bearing compounds, which offers hope that such pigs can one day be used to reduce phosphate pollution from farms.

Microcosm

E. coli and the New Science of Life

by Carl Zimmer

Pantheon, New York, 2008.
255 pp. \$25.95, C\$30.
ISBN 9780375424304.

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“The dire warnings,” the author writes, “that *E. coli* would create tumor plagues and insulin shock epidemics seem quaint today.”

A popular science book on *E. coli* may not sound like the most interesting read. However, *Microcosm* is just that. The next time you hear of an outbreak of nasty *E. coli* on the news, spare a thought for this minute

creature, which has arguably helped advance humanity far further than any other organism. Not only has it inhabited human guts for as long as we have existed, it has benefited almost all areas of the biosciences, from genetic engineering to evolutionary theory. To really understand life, it seems we must pay close attention to this bug’s life.

References

1. M. Holub, *Poems Before and After: Collected English Translations* (Bloodaxe, Tarsset, UK, 2006).
2. C. Darwin, *On the Origin of Species by Means of Natural Selection* (John Murray, London, 1859).
3. E. Humes, *Monkey Girl: Evolution, Education, Religion, and the Battle for America’s Soul* (Ecco, New York, 2007).

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A TASTE OF THE GONZO SCIENTIST

Scientists Invade Azeroth

A slime-filled sewer deep beneath a city may seem like a strange place to hold a conference, but none of the participants seemed to mind. I was co-hosting the first scientific conference (1) held in Azeroth, the virtual world inhabited by millions who play the game World of Warcraft (WoW), and a

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For more on this episode, including videos, go to www.gonzoscientist.org

lively discussion was under way about how to promote data sharing. Virtual worlds such as Azeroth are a treasure trove for psychological, social, and economic research (2). The atmosphere was casual and animated, like the conversations that happen between lectures at a good scientific meeting. But at this conference, the chat was happening on the computer monitors

of 200 to 300 people scattered around the globe. The participants were embodied as virtual characters standing in the cavernous chamber, many of them at that moment knee-deep in a green, bubbling pool.

The meeting was organized around three sessions. The first, “Research and World of Warcraft,” was chaired by Bonnie Nardi (University of California, Irvine) and Hilde Corneliusen (University of Bergen, Norway). They and three panelists discussed such issues as the potential and pitfalls of using WoW as a laboratory and how to ensure that research subjects give their consent. Following ethical guidelines for research in places like Azeroth may seem trivial now, but the panelists predicted that it will become crucial as the portion of people’s lives spent in virtual worlds grows.

Dmitri Williams (University of Southern California) chaired the second session, “Relationships Between WoW and the Real World,” which focused mostly on social psychology. It had a reading list as well as working papers put online by the panelists during the meeting. Then participants were introduced to Azeroth’s sophisticated gold-based economy, which has a real-world analog fueled by “gold-farmers” who sell their virtual wares for real money.

The closing session, “The Future of Virtual Worlds,” was overseen by the conference host, William Sims Bainbridge (U.S. National Science Foundation). The audience joined in a free-for-all forum, with questions ranging from the near-term outlook for the virtual worlds industry to the far-reaching prospects for human immortality in virtual worlds. Azeroth is already dotted with virtual beings who are memorials to real-life people who have died in recent years. “Will our ancestors someday be able to interact with virtual versions of ourselves?” mused Bainbridge.

What happened between the meeting’s academic sessions was highly unusual. On the first day, Bainbridge led an anthropological tour across one of Azeroth’s vast and dangerous continents. (After conducting over 2000

hours of ethnographic research in this world, Bainbridge knows it better than anyone.) Unfortunately, many of the conference participants were complete newcomers with vulnerable, low-level characters. Although the more powerful characters stayed in the lead, killing monsters along the way, there were a few casualties. Participants on the second day were treated to a concert sung by four banshees in an underground throne room. The third day included a dance that was followed by a massive attack on an enemy fort (which left all the participants dead). This was not your average scientific meeting.

The organizers recorded a transcript of the entire conference—including every comment, question, and answer—and an academic report is planned. Wayne Lutters, a computer scientist (University of Maryland, Baltimore County) who participated, described the conference as “historic.” And it has also generated an unexpected byproduct: the first science guild in WoW. Henry Lowood (Stanford University), the guild historian, is helping to create a wiki Web site for the guild that will include scientific



forums (both game-related and otherwise), a Facebook-like system for scientists to describe their research (and characters), and a calendar for academic and social events. Visit the guild homepage (3) to learn more or, if you like, to take part.

References

1. “Convergence of the Real and the Virtual,” World of Warcraft, 9 to 11 May 2008.
2. W. S. Bainbridge, *Science* **317**, 472 (2007).
3. www.scienceguild.org.

—JOHN BOHANNON

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