BOOKS: EVOLUTION

Mutated into Oblivion

Lynda F. Delph

I've never wanted to have kids. My mother thinks that this is proof of my selfishness. Perhaps she's right. But from an evolutionary perspective, selfishness would imply that I want more of myself, or at least more of my genes, in this world. To that aim, I might desire offspring that are genetically identical to me. Yet even then, being human, I can't make daughter clones of myself. Instead, we humans must reproduce sexually, which involves doubling up our chromosomes, splitting them apart twice, and then combining them with the chromosomes of another individual. Why do we go to all this trouble? Wouldn't it be easier to simply reproduce on our own? And why do we get sick, grow old, and die? Seeing the world through an evolutionary perspective can provide one with compelling insights into these and other provocative questions.

Mendel's Demon Gene Justice and the Complexity of Life
by Mark Ridley
Weidenfeld and Nicolson, London, 2000. 351 pp. £20. ISBN 0-297-64634-6.

released in the US as

The Cooperative Gene How Mendel's Demon Explains the Evolution of Complex Beings
Free Press, New York, 2001. 336 pp. $26, C$39.50. ISBN 0-7432-0161-2.

In his latest book, Mark Ridley, an evolutionary biologist at Oxford University, addresses the issue of how complex life, including humans, was able to evolve. His account touches on all the questions mentioned above. Readers intrigued by these topics are likely to find *The Cooperative Gene* (which was released last fall in the United Kingdom as *Mendel's Demon*) an engaging exposition of how evolutionary genetics can explain many of the apparently mysterious workings of life. Ridley's discussions will also interest those who want to understand how new technologies, such as gene therapy, can benefit humans. Because of his confident use of analogies, the author's explanations of complicated material can be followed even by readers who have very little knowledge of genetics.

Ridley begins the book by pointing out that for most of the approximately four billion years that life has existed on Earth, it was anything but complicated. In fact, for an amazingly long time life existed as little more than one-celled organisms that lacked a nucleus. He goes on to explain how complexity was finally able to evolve. The first step was the addition of more genes. These need to be copied when offspring are produced, and therein lies the problem. Adding genes meant that the number of copying errors, or mutations, would increase. One may be able to type a short sentence without error, but given an entire book to copy, many mistakes would be made. The longer the book, the more errors there would be. If the resulting version is then passed on to another person to copy again, additional errors would be introduced. Eventually, the book, riddled with errors, would be incomprehensible. This process of reproduction is like a ratchet, in that it is unidirectional: errors accumulate but are never removed. If we apply this analogy to life, the "Ratchet" (as it is commonly called), operating over thousands of generations, leads to an unreadable genetic code and the inability to produce viable offspring.

Divide to conquer. Through clonal reproduction, the anemone *Anthopleura elegantissima* forms vast aggregates of individuals alike in sex and color.

So how did complexity, in the form of organisms with a large number of genes, ever evolve? Ridley discusses a variety of methods for solving the error-accumulation problem (through prevention or correction) that have arisen over evolutionary time. For example, if there are two copies of every gene, one copy can act as a template for correction should the other be mutated; hence, most complex organisms contain two copies of every chromosome. At various places in the book, Ridley uses this redundancy method himself—perhaps to help the reader get the message right.

Although such methods are sufficient for relatively simple organisms, ways of enhancing cooperation among genes (such as gene-shuffling or "recombination") and an additional method of error reduction (purging or "natural selection") are necessary to prevent highly complex organisms from going extinct. Moreover, the evolution of sexual reproduction ("the ultimate existential absurdity") was, according to Ridley, "the big breakthrough that improved the efficiency with which natural selection removes mutations."

That sexual reproduction is the reproductive method of choice for most complex organisms is an enigma, because sex comes with substantial costs. These costs add up to a twofold advantage for an individual that reproduces clonally as compared to sexually. But, as Ridley points out, sex would not have arisen and been retained unless it offered sufficient advantages to compensate for these costs. The time scale over which the Ratchet works doesn't allow it to retain sex in large populations: A single clonally reproducing individual, with its twofold advantage, can replace a population of a million sexual individuals within tens of generations. Hence, long before the Ratchet carries the clones to extinction, sexual individuals will have been replaced by clonal individuals (a point that Ridley doesn't make entirely clear).

As Ridley notes, two ways to retain sex currently enjoy widespread support among evolutionary biologists. One, which the author touches on only very lightly, sees sex as a strategy against parasites. This "Red Queen" explanation suggests that if a parasite can attack you, it would also be able to attack any clonal offspring you produce. Therefore, you should reproduce sexually in order to produce variable offspring, some of which may escape attack from the parasite. In addition, by driving down the number of individuals within a clone, the Red Queen mechanism can aid the Ratchet; operating together, the two give a strong advantage to sex (*1*).

The other theory posits that sex is retained to help remove bad genes. This "Hatchet" mechanism (*2*), with an emphasis on mutation that conforms to the book's general orientation, is thoroughly discussed as the "damage escalator." The Hatchet requires that each mutation cause proportionately more damage than the previous one. As such, an individual with more than some threshold number of mutations will be "chopped out," and the process will purge mutations from

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the population in bunches. By combining the genes of individuals that differ in the placement and number of their mutations, sex manufactures mutationally loaded individuals for the Hatchet. The key point in this theory is that additional mutations must cause escalating damage. (For the example of the hypothetical book that was copied, sentences not only get harder to read, they get harder to read at an accelerating rate with each error.)

Is this assumption correct? Ridley argues it is, on the basis that it "follows from the way our bodies are built." However, scientists don't accept ideas purely because they make logical sense; they test theory with data. As Ridley concedes, "it will take facts to decide whether bad genes really do more damage as their numbers increase." Data collected so far suggest that the Hatchet is unlikely to be a general explanation for why sex is retained. Mutation rates are too low in organisms that still might have the ability to reproduce clonally (*3*) (not an option for any mammal), and consistent synergism between mutations is not detectable (*4*).

In his final chapter, Ridley borrows from 19th-century natural historians who saw angels as higher on the complexity hierarchy than humans. With tongue in cheek, he contemplates the habits of such celestial creatures. Clearly, Ridley tells us, angels must have sex and it must be of a form that concentrates errors even more effectively than does our Earthly method. Otherwise, they would mutate themselves into oblivion. I would only add that if they do have sex, they also suffer from parasites.

References and Notes

1. R. S. Howard, C. M. Lively, *Nature* **367**, 554 (1994).
2. The term "Hatchet" was coined by M. Turelli to describe the action of the explanation widely known as the mutational deterministic theory.
3. P. D. Keightley, A. Eyre-Walker, *Science* **290**, 332 (2000).
4. S. F. Elena, R. E. Lenski, *Nature* **390**, 395 (1997).

NOTA BENE: COMMUNICATION TECHNOLOGY

The Webs We Weave

Instant messaging, online romance, hackers, and nouveau riche technologists are only a few of its legacies. "It" is not the Internet, but the telegraph: the world's first world-wide web. Telegraphy was slow in coming, but after the first electric message traveled from Washington, D.C., to Baltimore, Maryland, on 24 May 1844 the consequences were explosive. Within a short time the world was wired; landlines connected every major city and transoceanic cables linked continents. Eventually, the telephone replaced the telegraph and boom gave way to bust—a cycle that was to be, and still is, repeated. As our own age comes down from the Internet hype of the 1990s, we can now see that we've been here before. These parallels propel an exhibit of information technology in the rotunda of the National Library of Medicine in Bethesda.

The Once and Future Web
Worlds Woven by the Telegraph and Internet
a play by Jerry James
May and June 2001, National Library of Medicine, Bethesda, MD.

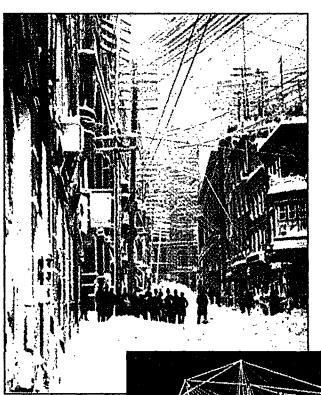
The Once and Future Web
Michael Sappol and Hunter Crowther-Heyck, Curators
National Library of Medicine, Bethesda, MD.
www.nlm.nih.gov/onceandfutureweb

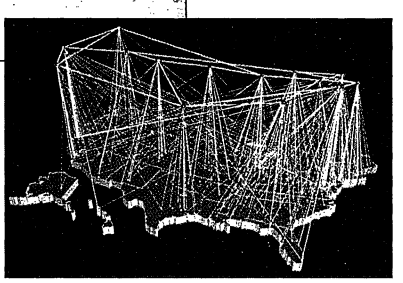
The Once and Future Web had its genesis when NLM director Donald Lindberg chanced upon science writer Tom Standage's book *The Victorian Internet* (Walker, New York, 1998). Standage argues that telegraphy was the first global communications network, and Lindberg insightfully recognized in this notion the possibilities for an exhibit comparing the new and old information ages.

Although not exhaustive, the exhibit captures the key moments in telegraphy, from its early days in France as a purely visual net of semaphore-like relays, through Samuel Morse's breakthrough code system, to telegraphy's rapid incorporation into commerce. The curators, Michael Sappol and Hunter Crowther-Heyck, have assembled a wonderful collection of information-technology artifacts in a compellingly presented display. The exhibit is set up in a ring, with the inside wall of the display devoted to telegraphy and the outer wall showing parallel developments of the Internet.

A walk through the exhibit gives a connected view of how each of these technologies evolved and of their social impacts. The development of Morse's code is framed against the creation of the first useful internetworking protocol (TCP/IP) by Robert Kahn and Vinton Cerf. Criminals are always early adopters of technology; the fraud and deception by telegraph hackers are neatly contrasted with popular fears about cyberporn and online scams. And the hype of the telegraph, which led to immense fortunes for some (though not its inventors), parallels our own era: dot-dash and dot-com.

Riding an encouraging trend that enlists theater to dissect and comment on technology (as in Michael Frayn's *Copenhagen*), the Library of Medicine commissioned a short play to accompany their exhibit. Playwright Jerry James has deftly packed a lot of history into a witty 40 minutes. Minimal in design, the piece is staged in a corner of the Library's History of Medicine reading room, and that provides all the backdrop that is needed. Cast for four actors, the play begins with an amusing account of an 18th-century experiment with a line of Carthusian monks holding copper wires, and a jolt of static electricity—the first demonstration that electric pulses could travel great distances and carry pain, if not information. James follows this with a rapid-fire tour through Morse's invention, the dawning of computers, and the creation of the Internet. Despite a few tired notes (such as a chorus line of "nerds" wearing taped-up glasses), the play wins by wit; how often do you get to see the founder of IBM as The Godfather? While not heavy going, the work does offer some provocative commentary on how sometimes outsiders make the breakthroughs: Morse started as a portrait painter, and the man who bankrolled the first transatlantic cable admitted not knowing a "telegraph from a tulip."





Enabling connections. In the 1880s, telegraph wires cluttered New York City. A century later, the National Science Foundation put together a high-speed, inter-network backbone, NSFNet, which became the heart of the Internet.

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It makes sense that the National Library of Medicine, an information technology organization of increasing sophistication, would host an exhibit such as this. One hopes for more cross pollination between scientists, museum curators, and performing artists—a vital way to reach the public that rides the infotech roller coaster. To update a famous quotation of Santayana, those who ignore the past are doomed to be swallowed by the hype of the present.

—DAVID VOSS