Six-Legged Soldiers: Using Insects as Weapons of War

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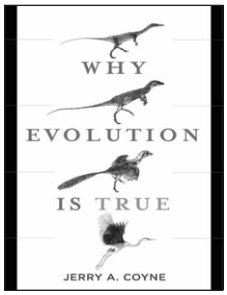
through the logic of how evolution makes specific predictions about the fossil record and the structural, developmental, and genetic characteristics of organisms. Many of the examples here—the evolutionary transitions of amphibians, birds, and whales—are well known but engagingly presented. The discussion of vestigial structures and pseudogenes is particularly compelling, clearly conveying how such features can make sense only in the light of evolution.



My favorite chapter was "The Geography of Life." As in several other chapters, Coyne begins with a brief historical anecdote—here the real-life Robinson Crusoe (Alexander Selkirk) and the fellow (nonhuman) inhabitants of his remote island—to explore evolutionary predictions about why organisms occur where they do. Coyne's diverse examples, drawn largely from terrestrial vertebrates and plants, interweave the themes of dispersal, contingency, and convergent evolution in explaining biogeographical patterns at both large and small scales.

The middle sections of the book focus on the mechanisms of evolution and diversification. Coyne clearly lays out the logic of natural and sexual selection and explains how these can lead to simple and complex adaptations. This provides a good summary of the abundant evidence we have for selection and adaptation, but the narrative flow of the material is sometimes clogged by the sheer number of examples—finches and field mice, test-tube evolution and antibiotic resistance, dogs and mustards. The discussion of speciation is masterful but a little pedantic—I kept wishing for jazzier biological examples here.

But Coyne returns to top form in his presentation of human evolution. Historical anecdotes, the abundant hominid fossil record, recent genetic and genomic analyses, and a little comic opera are combined to create a dynamic evolutionary history of us. It is hard for me to imagine an open-minded reader who will not be engaged and convinced by this presentation—evolution happened.

Coyne ends the book with a brief discussion of the extra-scientific dimensions of our challenge: Many people will not be convinced by logic and evidence alone, if they perceive "belief" in evolution as incompatible with their moral or spiritual beliefs. This discussion thoughtfully distinguishes between the evidence for evolution—and the high standards needed for such evidence—and the broader implications of evolution for human behavior, morals, and spirituality. *Why Evolution Is True* is a thorough and compelling introduction to the logic and evidence for evolution, for every monkey's uncle.

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CREEPY CRAWLERS AND TALL TALES

Six-Legged Soldiers: Using Insects as Weapons of War. Jeffrey A. Lockwood. Oxford University Press, 2008. 400 pp., illus. $27.95 (ISBN 9780195333053 cloth).

The use of insects as instruments of warfare and torture dates back some 5000 years and is a testament to the ingenuity and the cruelty of the human species. Jeffrey A. Lockwood, a professor of natural sciences and humanities at the University of Wyoming, makes the history of entomological warfare morbidly entertaining in his book *Six-Legged Soldiers: Using Insects as Weapons of War,* thanks to a lively writing style that ranges from the sardonic to the arch. But Lockwood falls short as a historian by relying on secondary sources of dubious accuracy and by accepting at face value several apocryphal tales that at best strain credulity and at worst reopen settled controversies.

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Six-Legged Soldiers describes three different types of entomological warfare: employing insects for direct attacks against humans, as vectors for transmitting infectious diseases, and as agricultural pests to destroy food crops. Two additional chapters focus on the utility of insects for defensive purposes (such as the use of fireflies to detect chemical nerve agents) and as models for the development of futuristic military robots.

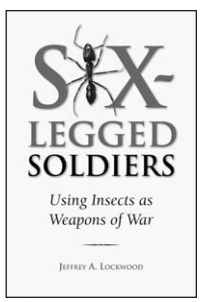
Lockwood begins by describing the historical use of stinging or biting arthropods—among them bees, scorpions, rove beetles, and assassin bugs—for battlefield attacks, siege warfare, and torture. He then discusses the devastating military impact of vector-borne diseases such as plague (carried by fleas), yellow fever and malaria (mosquitoes), typhus (lice), Q fever (ticks), and dysentery (flies) in conflicts from the Napoleonic campaigns through World War I. Until the modern era, far more soldiers died from diseases spread by insects than from bullets or artillery fire. As Lockwood observes, "The probiscus proved mightier than the sword—or the cannon" (p. 55).

Armies also made deliberate use of vector-borne pathogens as weapons of war, a practice that reached its dark apotheosis during the late 1930s in Imperial Japan. General Ishii Shiro established a top-secret biological warfare program in occupied Manchuria, where Japanese scientists cultivated billions of fleas infected with *Yersinia pestis,* the bacterium that causes plague, and loaded them into porcelain bombs for attacks on Chinese cities. In 1945, Ishii conceived of a plan for attacking San Diego with *Y. pestis*–infected fleas delivered by kamikaze aircraft. At the last moment, however, the chief of the general staff called off the operation, fearing that it would make Japan a pariah in the eyes of the world.

Between the late 1940s and the mid-1960s, several countries experimented with vector-borne diseases as biological weapons, but this approach fell out of favor when techniques for delivering microbial pathogens as windborne aerosols proved superior. Arthropods had several disadvantages as a delivery system: They were labor-intensive to produce, infected a more limited area than aerosol weapons, were unreliable because of the vagaries of insect behavior, and created reservoirs of infectious disease that would persist after a conflict ended. Although Lockwood contends that "Western nations would be well advised to take seriously the possibility that insects could be used to attack people and agriculture" (p. 298), the small number of countries and terrorist groups that currently pursue biological weapons are unlikely to use arthropods as a means of delivery. Still, one cannot rule out the deliberate spread of agricultural pests for purposes of economic sabotage.

The most serious flaw of *Six-Legged Soldiers* is its attempt to reopen old controversies. Lockwood devotes three chapters to allegations made by North Korea and China in early 1952, during the Korean War, that the United States had air-dropped over their territory 14 species of insects infected or coated with the pathogens that cause plague, anthrax, and other diseases. Although senior US civilian and military officials adamantly denied the charges, the Soviet Union supported them, as did other members of the Soviet bloc, and Chinese newsreels showed captured American pilots confessing to having engaged in clandestine biological warfare. An international scientific commission, chaired by a British scientist who was an avowed Communist sympathizer, affirmed the allegations against the United States after an inquiry based exclusively on evidence provided by North Korea and China.

Lockwood contends that the historical controversy over the Korean War allegations is still open, and that the US denials are not persuasive because "governments often disavow politically problematic knowledge" (p. 2). But Milton Leitenberg, of the University of Maryland, has shown convincingly that the charges were an elaborate hoax, based on scientific "data" fabricated by Chinese officials and their Soviet advisers as part of a systematic disinformation campaign (Leitenberg 1998). According to Leitenberg, the biowarfare allegations do not hold water for several reasons. All of the infectious diseases allegedly introduced by the United States were endemic to North Korea and China at that time; the alleged attacks occurred in winter, when the arthropods supposedly used as vectors would have frozen and died; the photographs that China provided as evidence showed insects that were misidentified or incapable of transmitting disease; and the captured American pilots who confessed to participating in biological attacks recanted after their release, claiming that they had been coerced.



Leitenberg notes further that at the time of the Korean War, the United States had not developed entomological weapons involving agent-vector combinations. He also obtained formerly secret documents from the Soviet archives stating that the accusations of US biological warfare were "fictitious" and that key pieces of evidence had been falsified. Finally, in 2004 the genomic analysis of more than a dozen isolates of *Bacillus anthracis* (the bacterium that causes anthrax), collected in 1952 in northeastern China after supposedly having been dropped from American aircraft, revealed that the strain was indigenous to China and unrelated to the Vollum strain used by the US biowarfare program, which ended in late 1969. According to two experts on biological weapons, this finding "makes it certain that the outbreak was natural, despite its unusual features" (Furmanski and Wheelis 2006).

Although Lockwood is aware of the strong historical and scientific evidence against the Korean War charges, he persists in giving them credence, arguing that several of the alleged attacks may have been real. "While the Soviets and North Koreans evidently collaborated to fake a crime scene," he writes, "this only shows that there was a single act of deceit, not that every incident was a sham" (p. 191). Elsewhere he contends that "some, perhaps many, governments harbored a nagging suspicion that where there is smoke there is fire—maybe not a conflagration of overt biological warfare but perhaps the flame of covert field testing" (p. 188). Yet *Six-Legged Soldiers* provides no new historical or scientific evidence to back up this invidious speculation.

Lockwood also finds credible the Cuban government's allegations that since 1962, covert operations by the United States or its agents have caused at least 10 major outbreaks of infectious disease that have seriously harmed the island's population and agriculture. During the cold war, Lockwood writes, "there can be little doubt that the Americans had the motive, means, and opportunity to conduct an entomological attack on Cuba" (p. 216). But microbiologist Raymond Zilinskas (1999) has analyzed the Cuban outbreaks and concluded that they all resulted from natural causes.

The most recent incident occurred in 1997, when the Cuban government called a consultative meeting of the member states of the Biological Weapons Convention to consider what Havana claimed had been a US biological attack. The Cubans alleged that on 21 October 1996, a State Department crop-dusting aircraft (en route to Columbia to eradicate coca plants) that overflew Matanzas Province in central Cuba through an authorized air corridor had released an insect pest called thrips, giving rise three months later to a major infestation that seriously damaged the island's crops. The United States categorically denied the charge, explaining that the crop-duster had generated a few puffs of smoke to warn off

an approaching Cuban aircraft, and provided records to show that the plane's spray tank had been reconfigured to carry extra fuel and was incapable of dispensing insects.

North Korea was the only country to support the Cuban allegations. Yet Lockwood gives them credence, noting that the thrips infestation was initially limited to Matanzas Province while farms further east were unaffected. Zilinskas, however, offers a plausible explanation. He notes that in the years before reaching Cuba, thrips had spread throughout the Caribbean region. Zilinskas believes that on 14–18 October 1996, winds from Hurricane Lili picked up the insects from areas where they were endemic and dropped them on central Cuba, a few days before the State Department crop-duster overflew the island. Indeed, the hurricane took nearly the same path across Matanzas Province as the US aircraft, albeit in the opposite direction.

In sum, by giving credence to allegations of US biological warfare that have been convincingly discredited, *Six-Legged Soldiers* does its readers a disservice and detracts from its central message that entomological warfare poses an enduring threat to society.

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WATER ACROSS THE WORLD: THE BIG PICTURE

Aquatic Ecosystems: Trends and Global Prospects. Nicholas V. C. Polunin, ed. Cambridge University Press, 2008. 512 pp., illus. $160.00 (ISBN 9780521833271 cloth).

Aquatic Ecosystems: Trends and Global Prospects is a very ambitious multiauthored volume that attempts to identify the current threats and future prospects for all types of aquatic ecosystems around the world. The high-quality, policy-relevant science described in *Aquatic Ecosystems,* together with the breadth of perspective, make the book a gold mine for students and scholars of aquatic ecosystems as well as for those involved in their management.

The book's major goals are to determine how the diverse aquatic ecosystems of the world might look in the year 2025, which of these aquatic ecosystems are the most threatened, what the primary drivers of change are, and how this information can be used in the conservation and management of these ecosystems. This is all done within the widely recognized context of a human population that has grown threefold in the past century and increased its water usage sixfold. While the global water crisis is widely recognized, this volume provides a wealth of information on which threats are the greatest for each type of the diverse array of aquatic ecosystems.

Nicholas V. C. Polunin, the editor of this volume, is a professor at the School of Marine Science and Technology in Newcastle in the United Kingdom, with a specialty in marine environmental science. He is also the current president of the Foundation for Environmental Conservation. Polunin has assembled an impressive array of over 100 leading aquatic scientists from 26 countries to contribute to this volume. *Aquatic Ecosystems* has its roots in a set of review papers that were published in the journal *Environmental Conservation,* the flagship journal of the Foundation for Environmental Conservation. This Swiss-based foundation was established in the early 1970s with a mission that is "holistically global…and…as widely international as possible." The comprehensive global array of aquatic ecosystems addressed in this volume and the broadly international group of leading aquatic scientists who contributed to it satisfy this mission and thus offer readers a valuable perspective on aquatic ecosystems at the broadest scale.

The volume is broken down into seven core sections by aquatic ecosystem type: flowing waters (streams and rivers, groundwater, and flood plains), still waters (small lakes and ponds, large freshwater lakes, and saline lakes), freshwater wetlands (temperate peatlands, temperate freshwater wetlands, and tropical wetlands), coastal wetlands (saltmarsh, mangrove, and estuarine), rocky shores (rocky intertidal, kelp forests, and coral reefs), soft shores (sandy, seagrass, and benthic continental shelves), and vast marine systems (marine pelagic, polar ice-edge, and deep-sea floor). The volume also includes multiauthored introduction and synthesis chapters. While it is clear that many of the chapters are extensions of recent reviews that cover a similar set of aquatic ecosystems and human impacts, a comparable compendium of the diversity of aquatic ecosystems does not exist. Each chapter starts by describing the characteristics of a given suite of aquatic ecosystems, summarizes the most critical threats to these ecosystems, and then provides either projections to the 2025 timeline or conclusions about what is needed for the effective management of these types of ecosystems in the future.

A common theme running throughout *Aquatic Ecosystems* emphasizes and compares the relative importance of more local-to-regional anthropogenic threats (such as eutrophication and contamination) to more global threats (such as climate change, sea-level rise, and invasive species). The volume makes clear that an integrated approach will ultimately be critical to successful man-

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