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Edmund Russell
Frontmatter
More information

Evolutionary History

Uniting History and Biology to Understand Life on Earth

We tend to see history and evolution springing from separate roots, one grounded in the human world and the other in the natural world. Human beings have become, however, probably the most powerful species shaping evolution today, and human-caused evolution in populations of other species has probably been the most important force shaping human history. This book introduces readers to evolutionary history, a new field that unites history and biology to create a fuller understanding of the past than either field of study can produce on its own. Evolutionary history can stimulate surprising new hypotheses for any field of history and evolutionary biology. How many art historians would have guessed that sculpture encouraged the evolution of tuskless elephants? How many biologists would have predicted that human poverty would accelerate animal evolution? How many military historians would have suspected that plant evolution would convert a counterinsurgency strategy into a rebel subsidy? How many historians of technology would have credited evolution in the New World with sparking the Industrial Revolution? With examples from around the globe, this book will help readers see the broadest patterns of history and the details of their own lives in a new light.

Edmund Russell is Associate Professor in the Department of Science, Technology, and Society and the Department of History at the University of Virginia. He has won several awards for his work, including the Leopold-Hidy Prize for the best article published in *Environmental History* in 2003; the Edelstein Prize in 2003 for an outstanding book in the history of technology published in the preceding three years; and the Forum for the History of Science in America Prize in 2001 for the best article on the history of science in America published in the previous three years by a scholar within ten years of his or her PhD. His previous books include *Natural Enemy, Natural Ally: Toward an Environmental History of War* (coedited with Richard P. Tucker, 2004) and *War and Nature: Fighting Humans and Insects with Chemicals from World War I to* Silent Spring (Cambridge University Press, 2001). He has published articles in the *Journal of American History*, *Environmental History*, *Technology and Culture*, and the *Washington Post*.

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This book is about continuity and change over generations,
so it is for the generation before me,
Anne Caldwell Russell (1934–1992) and Edmund Paul Russell Jr.,
and the generation after,
Anna Sankey Russell and Margaret Sankey Russell

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Edmund Russell
Frontmatter
More information

Contents

Cambridge University Press
978-0-521-74509-3 - Evolutionary History: Uniting History and
Biology to Understand Life on Earth
Edmund Russell
Frontmatter
More information

Figures

Cambridge University Press
978-0-521-74509-3 - Evolutionary History: Uniting History and Biology to Understand Life on Earth
Edmund Russell
Frontmatter
More information

Tables

Preface

Beverly Rathcke planted the seed of this book in a lecture she gave in an ecology class during my first semester in graduate school. She told us about cotton farmers who tried to control an insect pest by spraying an insecticide. This strategy worked for a while, but then a couple of puzzling things happened. The first was that farmers found themselves battling more and more **species**[1] of insect pests as the years went by. The second was that their insecticide lost its ability to kill insect species that it once had clobbered. Farmers substituted a new type of insecticide, which worked for a while, and then it, too, failed. They kept replacing insecticides, and increasing the frequency of spraying, until they had no poisons left. With no way of halting crop destruction by insects, farmers had no choice but to abandon growing cotton on thousands of acres.

To understand why farmers battled ever more species of pests over time, Beverly explained, one had to bring ecology to bear. One of the central concerns of this discipline is explaining the abundance of organisms. In farm fields, one finds many species of insects. Some species live in such large populations, and eat so much of a farmer's crops, that we call them pests. Populations of dozens of other insect species also live in farm fields, but most pass without notice because they cause no measurable damage to crops. In some cases, they are not pests because they eat something other than the crop. In other cases, they do feast on the crop, but their populations are too small to cause measurable losses. Several factors keep populations of insect species small, including predation by other species of insects. (Picture ladybugs preying on aphids.) This means that from the farmer's point of view, some insect species in fields are harmful (because they gobble up crops), but other insect species are beneficial (because they kill the insects that eat the crops).

A children's rhyme supplies an analogy. In the house that Jack built, Jack was like a farmer. The malt in the house that Jack built was like a crop. The rats that ate the malt in the house that Jack built resembled crop-eating insects. (Because we are talking about populations of animals rather than single individuals, we will make some species in the story plural.) The cats that ate the rats that ate the malt in the house that Jack built were predators akin to insects that prey on other insects. Now let us modify the story and add another species: the mouse. Mice lived in the house and ate the malt, but the cats killed them so efficiently that losses to mice were trivial. Mice resembled insect species living in farm fields in very small populations.

Now we have three species of mammals in Jack's house (not counting Jack) and a pair of predator-prey relations. One species, the rat, was numerous enough, and fond enough of malt, to qualify as a pest. A second malt-eating species, the mouse, inhabited the house in such low numbers one rarely noticed it and so it did not rise to pest status. A third species, the cat, benefited Jack by killing rats and mice. A similar cast of insect characters inhabited cotton fields – a large population of a crop-eating species (a pest), small populations of other crop-eating species, and populations of varying sizes of insect-eating (predatory) species.

Next imagine that Jack decided his losses to rats were unacceptably high. How might he respond? One way would be to import more cats. Another would be to poison the rats. Let us say Jack chose the latter route and scattered poison about the house. And let us say he chose a poison lethal to many mammalian species, including cats and mice, and these two species succumbed along with the rats. Furthermore, let us say other rats and mice lived in surrounding fields and migrated quickly into the house once the poison decayed. Cats, on the other hand, migrated in more slowly because they lived in the barns of distant neighbors. It would not be hard for populations of rats and mice to explode and for the mice to cause enough damage to join the rats as full-fledged pests. Now Jack lived in the house with lots of rats and mice but no cats. Ironically, in trying to kill one species, Jack accidentally helped a second species become a pest.

Insecticides had similar effects on insects in cotton fields. Many insecticides kill a wide range of insect species, beneficial as well as harmful. When spraying for one species of insect pest, farmers accidentally killed off populations of beneficial species of predatory insects, too. Freed from predation, populations of formerly rare plant-eating insect species blossomed into full-blown pests. Spraying thus had the ironic effect of increasing rather than decreasing the number of pest species. (Enough insect species have become pests as a by-product of spraying that entomologists have a term for them: *secondary pests*.) Spraying did not create new species, but it helped populations of several species become plentiful enough to cause economic problems. This explained why the number of pest species attacking cotton fields increased over time despite regular doses of insecticides.

To solve the second puzzle – the failure of insecticides to kill species they formerly controlled – Beverly turned to evolutionary theory. Unwittingly, cotton farmers had been carrying out experiments in **Darwinian evolution** by **natural selection**. In *On the Origin of Species*, **Charles Darwin** summed up his theory this way: if "variations useful to any organic being ever do occur, assuredly individuals thus characterized will have the best chance of being preserved in the struggle for life; and from the strong principle of inheritance, these will tend to produce offspring similarly characterized. This principle of preservation, or the survival of the fittest, I have called Natural Selection."[2]

Darwin would have little trouble applying his theory to insects in cotton fields. First, he would note that "variations useful" to individuals did occur. When spraying began, most individual insects of a given species in a given field (that is, a population) were susceptible to a given insecticide. A few individuals, however, were resistant to the insecticide because they happened to possess some biochemical machinery that detoxified the poison. So individuals varied in a "useful" **trait**. Second, Darwin would observe that this difference in traits influenced the "chance of being preserved in the struggle for life." Resistant individuals *survived* spraying more often than susceptible individuals. In Darwinian terms, spraying *selected* for one trait (**resistance**) and against another (**susceptibility**). Third, because of "the strong principle of inheritance," individual insects "produced offspring similarly characterized." Susceptible parents produced susceptible offspring, and resistant parents produced resistant offspring. Today we attribute "the strong principle of inheritance" to the passing of **genes** (strings of DNA with instructions for how cells should operate) for traits from parents to offspring.

Puzzle solved. Insecticides did not lose their ability to kill insects because the poisons changed; they lost their ability because the target insect populations changed. When spraying began, susceptible individuals outnumbered resistant individuals in a cotton field by far, which made the insecticide effective. But each round of spraying acted as a selective force, favoring the survival and reproduction of the resistant over the susceptible. Repeating this process over many insect generations increased the proportion of resistant individuals in the population until the insecticides failed to kill enough pests in the population to make it worth spraying. The insect population had evolved.

The encouragement of secondary pests and the evolution of resistance launched farmers onto something called the pesticide treadmill. In the short run, a pesticide worked, but in the long run, it failed. Farmers substituted a new insecticide, and the process repeated itself, ad infinitum. Beverly described this process as a **coevolutionary** arms race: insects evolved resistance, which led to a technological change by people, which led to more evolution for resistance, which led to more technological change, and so on. Farmers mimicked the Red Queen in *Alice in Wonderland*, running ever faster on the treadmill just to stay where they were.[3]

That evening, I gushed about Beverly's lecture to my wife as she was preparing dinner. (I think we were having burritos, but it could have been spaghetti. On our budget, we had one or the other most nights.) I have a feeling that even now, I have not identified all the reasons the story seemed so compelling, but I can point to some. It occupied the middle ground between the human and the natural. It showed reciprocal effects over time. It required the linking of tools from science (evolutionary ecology) and humanities (history) to understand events. You will see those same ideas in this book.

Acknowledgments

I owe many people debts for making this book possible. Beverly Rathcke and John Vandermeer, cochairs of my PhD committee at the University of Michigan, taught me about the role of human beings in ecology and evolution. I will always be grateful to them and to Earl Werner for encouraging me to write a history-oriented dissertation in a biology department as well as to three historians at Michigan (Richard Tucker, Gerald Linderman, and Susan Wright) for their support and advice as committee members. I wrote my dissertation while a predoctoral Fellow at the Smithsonian Institution's National Museum of American History, where curators and Fellows created a community that functioned much like a graduate program in history. Pete Daniel and Jeffrey Stine played especially important roles in helping a biologist become a historian. All these people helped me write my PhD dissertation, which used the history of chemical weapons and insecticides to examine the relationship between war and environmental change. The dissertation discussed the coevolution of insects and insecticides (among other things), and this book generalizes on that theme.

I was fortunate to publish my revised dissertation with Cambridge University Press (*War and Nature: Fighting Humans and Insects with Chemicals from World War I to* Silent Spring, 2001), which enabled me to work with Frank Smith and Donald Worster. They were model editors, patient and insightful in their advice. That experience led me to return to Cambridge with a proposal for a book on evolutionary history (defined in Chapter 1) using dogs as a case study. Frank advised splitting the book in two, with one book making a big argument about evolutionary history and the other focusing on the canine case study.

It was excellent advice and made me grateful, once again, to be working with such an astute and helpful editor. You have the first of those books in your hands, and I hope you will look for the dog book when it appears (also from Cambridge).

Frank Smith, Donald Worster, John McNeill (who now coedits the Cambridge series), Michael Grant, Brian Balogh, and Lucy Russell commented helpfully on the entire manuscript. Jonathan Wendel and Guy Ortolano offered excellent advice on Chapter 9. Brian Balogh also served as an important sounding board on our weekly walks. The book incorporates these people's suggestions about matters large and small. Tom Finger and Jennifer Kane have been model research assistants. Heather Norton and Jonathan Wendel responded with extraordinary care to queries about their work. Thank you all so much.

As editor of the journal *Environmental History*, Adam Rome played a key role in advancing the ideas in this book. I presented a conference paper with some rudimentary notions about evolution and history, and Adam suggested I turn the paper into an article. He did me a big favor by sending back the first two versions of the manuscript. The third, and much improved, version appeared as "Evolutionary History: Prospectus for a New Field," *Environmental History* 8 (April 2003): 204–228. *Environmental History* is a publication of the American Society for Environmental History and the Forest History Society, and I thank them for permission to reprint material from that essay in the chapter on environmental history (Chapter 11) and elsewhere in this book.

I owe a similar debt to the organizers of the 2002 Industrializing Organisms conference at Rutgers University: Philip Scranton, Susan Schrepfer, and Paul Israel. Philip and Susan edited a collection of essays growing out of the conference, which they subtitled "Introducing Evolutionary History." Introductory comments I made at the conference became a chapter in that volume (Edmund Russell, "Introduction: The Garden in the Machine: Toward an Evolutionary History of Technology," in *Industrializing Organisms: Introducing Evolutionary History*, ed. Susan R. Schrepfer and Philip Scranton [New York: Routledge, 2004], 1–16). I thank Taylor and Francis Group LLC for permission to reprint material from that essay in the chapter on history of technology (Chapter 10).

Figure 9.1, a photo of cotton bolls, appears here after a good-faith effort to find the rights holder. The photo appears without attribution in Arthur W. Silver, *Manchester Men and Indian Cotton 1847–1872* (Manchester University Press, 1966), 293. Manchester University Press has no record of the photo's source and claims no rights. The press and the history department at Temple University (the affiliation listed in the book for Mr. Silver) have no contact information. I was unable to find him in a Google search.

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Thanks go to my wife, Lucy, and our daughters Anna and Margaret for tolerating this project with good cheer. I could not live without you.

Charlottesville, Virginia
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