BOOK REVIEWS

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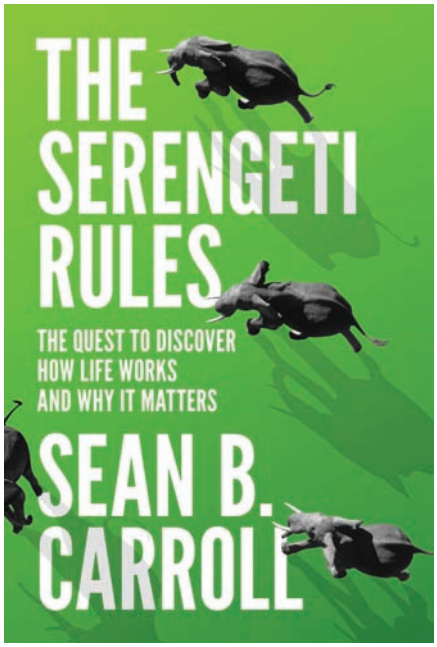

THE SCIENCE OF BIOLOGY

The Serengeti Rules: The Quest to Discover How Life Works and Why It Matters. By Sean B. Carroll. 2016. Princeton University Press. (ISBN 0691167427). 280 pp. Hardcover. $23.58.

Before I launched into *The Serengeti Rules*, the new book by Sean B. Carroll, I anticipated that I would read about top-down versus bottom-up control of populations and the experiments that scientists have employed to test and explain these patterns. But I should have known that Carroll would also take the reader on a fantastic journey through the history of the scientific discovery of many of nature's most important regulatory mechanisms, from molecules to megafauna.

Still practicing as a molecular biologist at the University of Wisconsin-Madison, Carroll is also vice president of science education for the Howard Hughes Medical Institute. In the spirit of Theodosius Dobzhansky, Carroll teaches us in *The Serengeti Rules* that "Nothing in biology makes sense except in the light of *regulation*." And he reveals this truth by way of a skill for which he is already well known: storytelling. Throughout the book, Carroll artfully and with careful research tells the stories of the scientists – and their discoveries – that have given us our current understanding of regulation in nature. But within the stories, Carroll also teaches the reader about the nature of science and scientific reasoning, as well as how scientific discovery is full of determination and success but also frequented by failure. The scientists and their stories are too many to summarize in a short review, but here are some highlights.

The book opens with "Part I: Everything is Regulated." Carroll begins this first section with his own descriptive story of a recent trip he took to the Serengeti, but the focus quickly transitions to 1896 and the questions and experiments of Walter Cannon. I had never heard of Cannon, but I should have. In short, we learn that Cannon was a Harvard University physiologist who questioned why fear and stress affect an animal's physiology. He hypothesized that an animal's normal physiological states "remain steady because factors exist that resist change in either direction, positive or negative," but that stress disrupts many of an animal's highly regulated mechanisms. Cannon's most important test of this hypothesis came while he was assisting in a field hospital in Europe during World War I. Carroll recounts how Cannon noticed patterns in the wounded soldiers that often led to death, including blood pressures that dropped to levels as low as 50 when blood bicarbonate ion and pH also dropped. With regulation in mind, Cannon reasoned that adding bicarbonate ion to the soldiers' blood could raise blood pH and also blood pressure. The method worked and allowed wounded soldiers to be, in the words of Cannon, "snatched from death." After the war, Cannon continued with his physiology and regulation research and eventually described the steady states that the body maintains within a narrow window, like blood pressure and blood pH, with a new term, *homeostasis*.

Part I also introduces us to another scientist who, given my own background in trophic ecology, I should have known: Charles Elton. It was Elton who, from years of fieldwork in hostile Arctic ecosystems, abducted the idea of scarce resources from economics and described how the availability of food regulates the sizes of animal populations. Indeed, it is Elton who published the first diagram of a complex food web.

"Part II: The Logic of Life" includes stories from the fields of molecular and cellular biology and is where Carroll, the molecular biologist, really teaches to his strengths. For example, it was in Part II that I found Carroll's use of models to illustrate and simplify complex interactions extremely helpful: A indirectly regulates C by regulating B; the buildup of A inhibits its own synthesis – and on. It was through the work of scientists like Jacques Monod and François Jacob that we first learned about these negative feedback mechanisms in the context of enzyme function. Among many other great stories in this section, Carroll also recounts how the discovery by Janet Rowley of chromosomal translocations eventually led to the invention of the successful cancer drug Gleevec. Each of these stories was new to me.

"Part III: The Serengeti Rules" begins with a quote from one of the most well-known and influential ecological papers of the last half century: "The Regulation of Populations Must Be Known before We Can Understand Nature and Predict Its Behavior." When I was in graduate school studying ecology, all a person had to say was "Hairston et al. 1960" and you would know they were referring to the "green world hypothesis." This idea frames the stories in Part III, in which Carroll describes regulation at its largest scales. With a single publication, Nelson Hairston and

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his colleagues initiated a paradigm shift in our understanding of how populations and their interactions are regulated through trophic cascades, and in how we study them. The results of a few of the more famous ecosystem experiments are in our biology textbooks and have been part of our curriculum for years. For example, the observations by Jim Estes and John Palmisano on how sea otters regulate kelp forests by eating sea urchins. However, what is not in our textbooks are the well-told stories, and Sean Carroll makes it clear that stories, especially the ecological ones, are salient – if indeed one of our main goals in teaching is to leave lasting impressions on our students so that they can achieve a deep understanding and respect for how the natural world works.

Back in the Introduction, Carroll writes that "Diseases . . . are mostly abnormalities of regulation, where too little or too much of something is made." From molecules to megafauna, regardless of the scale, Carroll teaches the reader that to understand the disease state of a system, one must intimately understand how that system is regulated.

Sean Carroll's new book, with his thesis that *everything is regulated* backed by stories of discovery and inquiry, will enhance the way I teach biology. I am convinced that *The Serengeti Rules* should be required reading for students in all fields of science, but especially those pursuing careers in biology education.

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Sean B. Carroll has often talked about the power of stories to engage and educate people about biology, and science in general. He is a very good storyteller himself. His previous books have been about evolution. But this book is different. *The Serengeti Rules* has one common theme – regulation. Carroll does a masterful job of connecting stories of scientists' work and discoveries of various biological phenomena from the molecular to the ecosystem level in this book. At first glance, the reader might not see the connections among all of the seemingly unrelated topics listed in the table of contents, but Dr. Carroll keeps coming back to what he says in the introduction, " . . . even though the specific molecular and ecological rules differ, the overall logic is remarkably similar."

The book is broken down into sections with an Introduction, followed by "Part 1: Everything is Regulated," "Part 2: The Logic of Life," "Part 3: The Serengeti Rules," and he brings everything together in his "Afterword: Rules to Live By." The Introduction takes us on a family trip to the Serengeti National Park. Carroll shares his thoughts and feelings, but he also shares some insightful observations. We know that there are rules that regulate the molecules and cells in our bodies and we also know there are ecological rules that regulate ecosystems. He calls these ecological rules the "Serengeti Rules" and says that we must understand and apply these ecological rules if we want to reverse the harm that humans are causing all over the world.

Part 1 focuses on the stories of the researchers and their discoveries on regulation, from the molecular to ecosystem level. Carroll grabs our attention when telling us the story of a physiologist whose research led to an understanding of what we commonly call the "fight or flight response". But that wasn't all he did. He revolutionized the treatment of shock. We come away with the message that regulation is responsible for maintaining homeostasis and when that regulation isn't working properly, it's a physician's job to restore homeostasis.

I also thought Carroll did a really great job of recounting the story of Charles Elton, a naturalist who studied regulation at a much larger level, the ecosystem. I felt like I was there with Elton when he studied organisms in the Arctic. Elton concentrated on what enabled each species to survive in the extreme conditions, in other words, their adaptations. He created what he called "food chains" and "food webs". But Carroll tells us he didn't stop there! Elton continued his research, concentrating on predator and prey populations. The author drives home the message that homeostasis is maintained in communities just like it is in a human body.

Part II begins with the story of two men whose names are familiar to biologists, Jacques Monod and François Jacob. In doing this, Carroll takes us back to the molecular level. Monod began as a student researcher in the Arctic too, but unlike Elton, his interests took him in another direction and a much smaller scale – bacteria. He noticed a difference in the growth rate of bacteria grown in different combinations of sugars. He thought it might be due to "enzyme adaptation" in the bacteria. Working together, Jacob and Monod gave us the model for prokaryotic gene regulation. Carroll makes a point of explaining how their work also led to the four general rules of regulation. The author advises you to bookmark the page where these rules are found because you'll need to refer to them again, and that's exactly what I did. Jacob and Monod knew that the results of their studies in bacteria would be applicable in much larger and more complex organisms. Even though I knew the outcome of this story, I couldn't wait to turn each page to find out what happened next.

Although it may not be apparent by the title, Carroll takes us on a much longer and complicated journey in the next chapter. There are many players in this story and the end result is well known – the use of statins in controlling cholesterol levels, more specifically LDL levels. I like the way Carroll takes us to the heights of the Andes at the beginning of the chapter and how the journey slowly unfolds from there and ends in research labs. Like Jacob and Monod, these scientists concentrated on enzyme regulation, but on a much larger scale. When reading about the rules of cholesterol regulation, you'll need to go back to the page you bookmarked to review the general rules of regulation. You might also want to read this chapter more than once.

Carroll tells us stories about genetics and cancer in the last chapter in this section. It was one of my favorites, but perhaps that's due to some gender bias. I finally read about a female scientist! Janet Davison Rowley's work turned out to be extremely important even though the medical establishment didn't immediately recognize her groundbreaking work on chromosomal translocations. Her work put together with the research of others in discovering how viruses cause cancer led to the discovery of proto-oncogenes and oncogenes and their role in cancer. The second part of the chapter relays the stories of the scientists learning about the "broken brakes", or tumor suppressors and their role in causing cancer. Again, throughout the entire chapter Carroll reminds us about the rules of regulation and what happens when those rules aren't working.

In Part 3 the author brings us back to the Serengeti Rules with stories about more "pioneers" whose work revealed the rules that regulate populations. We begin our first story on the Olympic Peninsula with a college professor studying tidal pool communities, specifically the role of starfish (a predator) in this community. The intrepid scientist returns again and again to remove all the starfish from one community but not from another one and he does this for 5 years! He sees tremendous negative changes in the communities without starfish. Other researchers conduct experiments in other communities like kelp forests, freshwater streams, and on islands, all with similar results. This confirms what we've already learned about negative regulation in chapter 3 and this is when the author reveals the first 2 Serengeti Rules.

We return to the Serengeti in the next chapter and we learn more about its ecology. Dr. Carroll introduces us to Tony Sinclair and many other dedicated scientists who have spent

years studying its wildlife. We learn how disease, species interactions like competition and predation, environmental changes, and even animal size plays a role in the history of the Serengeti and why it still exists today. All of the examples of regulation at different levels mentioned in previous chapters are reinforced. Carroll reveals the four remaining Serengeti Rules and reminds us that these rules apply to all systems, from the molecular to the ecosystem level. He also emphasizes that these rules apply to all levels and we must find a way to fix the bad things that happen to our planet when those rules are broken.

It's called cancer, but it's a different kind of cancer. The remaining chapters chronicle the many ways that human activity has caused this. Carroll shares many examples, including toxic algae blooms in lakes and other bodies of water due to pollution, deforestation for food production, proliferation of harmful insects due to using pesticides, and fish population crashes caused by overfishing. Then he asks what rules of regulation have been broken and by whom. He asks if we can use our understanding of these rules to fix any of these problems.

Carroll does offer some ways that humans have made positive changes that restore the rules of regulation in the last 2 chapters. These include the reintroduction of wolves in Yellowstone National Park and improving water quality of lakes in the Midwest in order to restock popular fish species. Then we travel to Africa, to the Gorongosa National Park in Mozambique and learn how it is making a comeback after a prolonged civil war through the efforts of many people, especially Greg Carr and the Gorongosa Restoration Project. What is very cool about this project is that it's working and that the needs of the people living near the park are being considered in the process with jobs and other sources of revenue.

Sean Carroll does a consummate job of coming full circle at the end of the book. I love that fact that he includes some of the lyrics from Led Zeppelin's *Stairway to Heaven* on the first page of the Afterword. This book offers hope that we can make a difference, that we can follow those rules, and that things can get better on our planet, our home. It is well written, meticulously researched, and easy to read. I also learned more about the serendipitous nature of scientific discovery. I thoroughly enjoyed this book and highly recommend it to both teachers and students.

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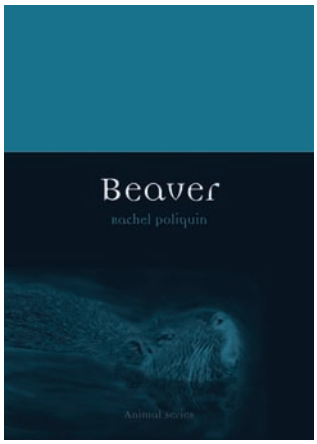
ANIMALS



Beaver. By Rachel Poliquin. 2015. Reaktion Books. (ISBN 9781780234236). 224 pp. Paperbact. $19.95.

Eagle. By Janine Rogers. 2015. Reaktion Books. (ISBN 9781780233376). 189 pp. $19.95.

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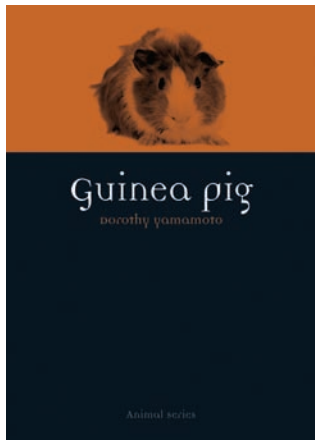

Guinea Pig. By Dorothy Yamamoto. 2014. Reaktion Books. (ISBN 9781780234267). 183 pp. $19.95.

These five books are part of a series devoted to the natural history of each animal and the animal's impact on human history, primarily as reflected in various aspects of human culture. Reviews of three other books in this series were published in the November–December 2015 issue of *ABT* (vol. 77, pp. 713–714). Here, I give a short, general introduction to the series and then separate reviews of each of the books listed above, which are followed by Cate Hibbit's reviews of three more books in the series.

As with the previous books, the greater portion of each is devoted to the role the animal has played in the arts, literature, and religion. As a biology teacher, you may want to use this series to involve students who are not enthusiastic about biology but who have an interest in history and/or the arts and literature. And there are many quirky nuggets of information that you may want to incorporate in your teaching about ecology, conservation, genetics, and the process of classifying organisms.