

## EVOLUTION

# What Led to Metazoa's Big Bang?

Christopher J. Lowe

The Ediacaran and Cambrian periods witnessed a phase of morphological innovation in animal evolution unrivaled in metazoan history, yet the proximate causes of this body plan revolution remain decidedly murky. The grand puzzle of the Cambrian explosion surely must rank as one of the most important outstanding mysteries in evolutionary biology. Evidence of early representatives of all the major animal phyla first appear abruptly in the Cambrian (starting 542 million years ago). This spectacular morphological diversity contrasts strongly with Precambrian deposits, which have yielded a sparse fossil record with small, morphologically ambiguous trace fossils or the enigmatic but elegant creatures of the Ediacaran fauna. Following the Cambrian, despite a rich fossil record that documents impressive morphological diversification among animals, no new body plans have been revealed, leaving the Cambrian as the apparent crucible of metazoan body plan innovation. Although it is only in the various Cambrian fossil assemblages that this exuberance of animal life first makes an appearance, molecular clock calculations estimate divergence times of the major metazoan lineages well before the Cambrian. That suggests a prolonged period of cryptic evolution in the Ediacaran not well represented in fossils, adding further intrigue to the puzzle.

The range of hypotheses proposed to explain the Cambrian explosion is as diverse and broad as the fossils they seek to explain. Researchers from a wide range of sciences (including geology, ecology, developmental biology, and genomics) have all made substantial contributions toward unraveling the causes of this key puzzle of animal evolution. Yet in most cases, their findings have been consid-

ered independent of one another. In *The Cambrian Explosion*, paleontologists Douglas Erwin (National Museum of Natural History) and James Valentine (University of California, Berkeley) make a heroic attempt to synthesize these disparate fields. In the process, they have distilled a unique contribution that should be a required addition to any biologist's bookshelf.

The book's first two sections set the stage. The authors introduce the geological and environmental contexts of the Cambrian and Ediacaran and then the animal phyla and fossils. They strip the characteristics of each phylum down to the basics, not burdening readers with too much detail but providing enough for them to appreciate how recent modifications to animal phylogeny have strongly revised our understanding of early animal diversification. This section is well illustrated with clear and simple diagrams. I found the fossil chapters particularly compelling, as they brought together key Ediacaran and Cambrian fossils, discussed within the framework of contem-

porary hypotheses of animal relationships. Quade Paul's vivid color reconstructions, displayed next to photos of the fossils, bring to life the stunning morphological diversity and ecological context that are often lost in the rather clinical descriptions of these mysterious fossils from the primary literature.

The authors also review molecular biology's substantial contributions to solving the grand puzzle of the Cambrian explosion, which have at times been at odds with interpretations derived from fossil data. Comparative developmental genetic studies and genome sequencing projects from diverse metazoan phyla have revealed some of the genetic innovations that were likely responsible, in part, for the increase in animal complexity. These new data may help us reconstruct ancestral morphological features of the mysterious stem lineages of the Ediacaran, by reconstructing ancestral gene complements and by inferring gene regulatory networks that have key roles in setting up the body plans of extant animals. However, our understanding of how to relate genomic and developmental regulatory complexity to organizational and morphological complexity remains in its infancy.

In the book's last section, Erwin and Valentine begin to integrate and synthesize the introductory material. They hold that many previous attempts at developing hypotheses to explain the Cambrian explosion focused on a single cause, which was often inconsistent with data available from other fields.

They argue convincingly that complete understandings of animal origins and the explosion's "great evolutionary puzzle" can only be achieved by considering the relative importance of three main aspects: substantial change in the environment, which differed greatly from the present day; the sequential acquisition of genetic and developmental innovations that gradually increased body plan complexity during the Ediacaran and Cambrian; and the establishment of ecological relationships among animals that ensured that new metazoans with novel body plans succeeded in their new environments. Ecological opportunities for novel morphological innovations were not just provided by physical changes to the environment but also driven by changes produced by the activities of animals themselves.

## The Cambrian Explosion The Construction of Animal Biodiversity

by Douglas H. Erwin and  
James W. Valentine  
Roberts and Company,  
Greenwood Village, CO, 2013.  
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**Difficult to interpret.** *Herpetogaster collinsi*, a tentaculate soft-bodied fossil from the Burgess Shale, is a possible stem Ambulacraria.

The reviewer is at the Hopkins Marine Station, Stanford University, 120 Oceanview Boulevard, Pacific Grove, CA 93950, USA. E-mail: clowe@stanford.edu

Readers of *The Cambrian Explosion* will likely have either little background or some expertise in one of the disciplines covered. Falling into the latter camp, I have largely considered causes of the Cambrian explosion from the perspective of molecular genetics and genomics. Erwin and Valentine illuminate clear links between seemingly disparate disciplines, and they make a compelling case that substantial progress toward understanding the origins of animal diversity will not be achieved through adding isolated gains in individual fields. It is futile to hope to explain such a major evolutionary event without embracing an interdisciplinary approach.

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## COMPUTERS

# Lovely Spam! Wonderful Spam!

Jennifer Golbeck

In the 1970s and 1980s, spam was that annoying co-worker who comes into your office when you're up against a deadline to give you his take on the last episode of *Battlestar Galactica* when you don't watch *Battlestar Galactica*. Today, spam is a horde of zombies, beating against the walls of the old farmhouse you're holed up in, bent on eating your brains.

The world has changed a lot over the past few decades. Finn Brunton's *Spam: A Shadow History of the Internet* traces spam's history—from its early days, as annoying messages taking up valuable bandwidth, to the present, when it accounts for the overwhelming majority of all e-mail and CAPTCHAs (*J*) routinely demand that we prove our humanity.

Brunton (a digital media researcher who is moving to New York University) breaks the story of spam into three eras: the largely pre-Web days from 1971 to 1994, Web and e-mail spam from 1995 to 2003, and botnets and powerful spam filters since 2003. His descriptions of the three eras are deeply engaging, and together they provide a fascinating account of the history of the Internet, as the book's subtitle implies.

The reviewer is at the Human-Computer Interaction Lab, University of Maryland, College Park, MD 20742, USA. E-mail: golbeck@cs.umd.edu



Right from the start, and using great storytelling, Brunton immerses readers in the early days of the Internet. A community of computer scientists and techies were learning to interact in a new medium. Through a series of vignettes, the author paints a picture of the Internet's infancy: the technological and bandwidth limitations (now all but forgotten), the communities that sprang into existence, and key moments and figures in the history of spam.

His play-by-play account of early abuses offers an entertaining tour through the past. Brunton discusses the misbehaving scammers

on USENET, including the person whose 1988 message asked everyone on the Internet to donate one dollar to "JJ's College Fund" and the dramatic response of the (then) small community to punish that abuser. He also describes early attempts at technical solutions and their resulting failures. For

example, the Automated Retroactive Minimal Moderation program (ARMM) trapped bad messages on USENET, but unfortunately it then sent notifications that were themselves identified as spam, touching off a chain reaction of bad posts.

This early era ended as commercial use of the Internet exploded, accompanied by unabashed use of spam for marketing. In describing the second era, Brunton relays how community-oriented solutions failed to stop the growing spam problem and how their failure fueled the development of increasingly sophisticated technical solutions and government policies.

Eventually, spam matured into a largely criminal enterprise. Brunton documents the world of botnets, link spam, and social spam. This shift in spammers' strategy cor-

responds to a change in victims and how they are targeted. Only the most naïve users are expected to respond to the pitches, while other victims are exploited to build legions of botnets to distribute spam. The fundamentally decentralized nature of the botnets means the spamming cannot be shut down at the source.

The book began its life as a dissertation, and in some places that origin shows. The text occasionally strays from its otherwise excellent flow of narrative, delving into some unnecessary detail. An early five-page discussion of *charivari* (a sort of harassing

mob) versus vigilantism is one such example; the longish, nontechnical overview of Google's PageRank algorithm is another. Such rough spots occur a bit more frequently later in the book. Nonetheless, they are only noticeable because the rest of the text flows so smoothly, and they do not detract from the book's value.

One of Brunton's core messages is that spam is both a social and technical problem. The recent explosive growth of social media leads many to think that social interaction and communities are a relatively new phenomenon online. The book shows, however, that communities were around on (and, indeed, defined) the Internet from its earliest days. Spam, by its nature, is a reflection of the community's standards, as they have progressed with the technology.

*Spam* will fascinate readers who aren't experts in the subject matter by shedding new light on the culture and function of their Internet experience. But it has plenty to offer computer scientists and online-community researchers as well. As someone who was born after the Internet, Brunton's account has transformed what was in my mind a collection of dates and rather bland history into a richer, much more vivid image of community and interactions. More important, the book made me realize just how in flux these systems are. As we live with the fact of spam and antispam technology, it's easy to lose track of how the landscape is shifting around us. This masterful telling of the history illustrates just how much has changed and how we fit into the larger story.

### References and Notes

1. The acronym, based on "capture," stands for "Completely Automated Public Turing test to tell Computers and Humans Apart."

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