
Everything about the Cambrian Explosion sounds exciting: it is the Big Bang of evolution, if you like. Along with the extinction of the dinosaurs at the Cretaceous–Paleogene boundary, some 66 Ma, it is the evolutionary event that sticks in everyone’s mind, when all of the animals apparently appeared in a well, explosion, over 500 Ma. Given this fame, or even notoriety, it is rather surprising how poorly the topic is served by book-length treatments.

Of course, there are books about it, but many of these turn out to be about particular aspects of the subject rather than attempting a comprehensive treatment. Given that a “comprehensive treatment” needs minimally to span the topics of fossil preservation and interpretation, oceanic and atmospheric geochemistry, animal systematics and development, not to mention ecological theory, sedimentology, and radiometric and stable isotopic dating (along with a slew of others) perhaps this is not very surprising. Anyone who sits down and attempts such a thing must sooner or later be faced with a feeling of helplessness. That the thing can be done at all is thus a thing of wonder. That two of the most experienced and interesting commentators on the topic have done so is a cause for some celebration, then.

Having said that, one must at once admit, as the authors themselves cheerfully do in their introduction, that this volume is not all things to all people. It was written at the request of Nicole King, so that her graduate students could have a useful reference guide to the Cambrian explosion—a role that this volume eminently fills. It is sturdily constructed, beautifully illustrated, and does indeed make a fair stab at covering most of the major issues. After the introductory material, successive chapters cover the geological context of the Cambrian explosion, including stratigraphy and correlation; and approaches to reconstruction of the late Precambrian–Cambrian world (a transition that took place around 635–500 Ma). The next chapter covers an introduction to animal classification, including molecular phylogenies, and then plunges into a primer of animal morphology, starting with the likely sister group to the animals, the choanoflagellates, and ending with lophotrochozoans. The authors then turn their attention, in a particularly well-illustrated chapter, to the enigmatic “Ediacara”-style biota that existed from about 579 Ma to around the beginning of the Cambrian. This leads naturally into a very substantial chapter covering the Cambrian faunas, including some excellent, if on occasion somewhat disturbing, reconstructions of Cambrian animals. Perhaps, we can be grateful that the recent description of Spriobranchus tenuis (Caron et al. 2013) came just too late for inclusion in the book. The authors also struggle here with the problematic nature of many Cambrian organisms, taking deuterostomes, lophotrochozoans, and arthropods as their examples. In a short closing summary, they then attempt to present what they think the data mean in terms of diversity, which is relatively straightforward, and disparity, which is not.

The following section deals with the evolutionary processes that might lie behind these patterns. First up come the ecological patterns of change, where the topic of “ecosystem engineering” features prominently, and then an informed discussion of the genetic basis for body plan development and its possible involvement in body plan evolution. Finally, in a relatively brief section of the book, the authors sum up their views on the missing “ghosts”—organisms that we know must have been present at some time but that have left no trace—and the implications this has for the integration of the data they discuss in the book, especially that from developmental sources. A substantial appendix records first evolutionary appearances of phyla and classes.

Such is a (very brief) outline of the contents. How should it be judged? First some quibbles. Like many first editions, it suffers from its (inevitable) fair share of slips—for example, veterans of the Cambrian literature on the hunt for misspellings of Stefan Bengston’s name will not be disappointed. The specimen of Cloudina illustrated is not from Namibia but China;
and some of the small shelly fossil assignments are somewhat surprising—for example, a figure caption claims that what I think is probably _Mobergella_ is a “stem bivalve,” which is certain to raise some eyebrows. The summary “best guess” phylogeny on page 75 is peculiar—apart from (I assume) inadvertently placing the protostome–deuterostome boundary in the wrong place (between echinoderms and hemichordates!), it also has some rather strange sister-group relationships, such as between brachiopods and rhaditdioporphans. In any case, it is flatly contradicted in many places by the microRNA tree on the very next page.

As well as presenting the basic evidence for the Cambrian explosion, the authors also have a thesis to defend. This is that the fossil record of the early Cambrian shows a marked clumping of taxa—and they point out how dissimilar the fossil record is compared with known ecological radiations, such as that of, for example, cichlid fish (a pattern that was pointed out as long ago as 1850 by Adam Sedgwick, incidentally). As a result, they consider that to think of the Cambrian explosion as an adaptive radiation is to stretch the term to its breaking point. As a general rule, this may or may not be true—trilobites, the most iconic and diverse of all Cambrian fossils, hardly seem to follow it (Foote 1990; Budd 2013). However, assuming it is true, what are we to make of it? Can we take it, as the authors shyly hint, that the underlying pattern—now lost to us—was also different from adaptive radiations? That authors quite rightly reject any notion of “saltational” leaps in evolutionary organization. However, at the same time, they want to attribute the large gaps between the known organisms—their disparity—to a particular type of evolutionary mechanism related to how the developmental genome is organized. I have to say that I find this claim to be problematic, particularly as the authors themselves (p. 72) seem elsewhere to admit to these gaps resulting from a failure of the fossil record to preserve the intermediates that must have existed. If such intermediates existed but have not been preserved, then in what sense is the developmental genome controlling and restricting the known clumped pattern of morphologies (or rather, how could we know how to partition the effect between the genome and preservational vagaries)? The problems with such a view can be seen in other ways as well. The authors want to loosely correlate levels of change within the developmental genome with the Linnean hierarchy. Valentine has published more clearly than anyone else that, although both are hierarchies, they are very differently structured, and thus one cannot simply map one on to the other. What I would like to see is not the usual lineage of “phyla-classes-orders” with “kernels-gene batteries,” etc. but, rather, a mapping of the attainment of developmental mechanisms onto a phylogenetic tree of the phyla. As soon as you try to do this, the problems of asserting a hierarchical developmental control of evolutionary morphological conservation become apparent—the phyla simply do not appear on the tree in the right way in order

for this to make sense. In other words, it seems to me that the approach taken in the book—it is by no means necessarily an invalid one, incidentally—is developmentally an “extantist” one—by making the assumption that the developmental maintenance of today’s organs and systems is the same as their developmental origin. But if we are to gain any insights from the field of “evo-devo” today, surely one must be that development must itself have evolved—a point, however, that is curiously resisted by many of its practitioners.

One of the good things about the book is the insistence on the importance of all aspects of development, phylogeny, ecology, and environment in coming to a mature understanding of the Cambrian Explosion—in contrast to some previous efforts at “explaining” it that can, I think, remain nameless. There is, for them, no magic bullet that is the ultimate fix for this problematic event. In perhaps the most interesting part of the book, the authors grapple with the problems of ecosystem engineering and niche construction—the complex feedbacks between organisms and environments that enable and shape radiations. It is an eerie thought, of the first mobile bilaterians appearing at one place in the world, and spreading across it, creating epoch-making change in their wake and adapting on the way. But did they arrive at the far ends of the earth in the same shape as they left its departure point or had they already massively diversified into the virgin territories they encountered—telegraph, or Chinese whispers, if you like? Such timing differences might have had significant effects on all subsequent evolution, as in the former case diversification would be into ecospace that was in some sense already occupied, and in the latter without such constraint.

One of the frustrating things about the Cambrian Explosion, which the authors (perhaps understandably, given their target audience) politely do not fully bring out, is how poorly constrained the critical time period still is. As a result, it is simply impossible at the current time to get answers to apparently sensible questions like “where did the first burrowing trace fossils appear?” and “Which trilobite genus is the oldest?” and so on. Yet, if we really want to understand the delicate interactions between environment and evolution that may stand behind all subsequent events, it might well be that it is exactly this detail that we need—and this is some way off. In other words, although we can see the spectacular painted backdrop against which the Cambrian Explosion is played out—the Neoproterozoic glaciations, the continental collisions and break-up, and the wild fluctuations in geochemistry throughout the period—it remains difficult to see how these relate in any detailed and interesting way to evolutionary innovations at the base of the bilaterian animals and before. (Unlike the authors, I find it hard to image the sponges arising almost 200 myr before the base of the Cambrian.) Erwin and Valentine quite sensibly do not offer any glib answers here, but their compilation and enlightened discussion of much of the relevant data in
one volume will surely open windows for their readers into the depth and complexity of what they rightly describe as the “once-in-an-era happening” that is the Cambrian Explosion.

Erwin and Valentine’s book is a good introduction to the topic they address, and perhaps the best available. This is not exactly a book for specialists—and the authors themselves admit to this. It does not, for example, really dig into (in particular) the geological data to show where all of the uncertainties lie, but presents a more or less optimistic “consensus” view of where we are at the moment. This geological part has been consciously written to be accessible to all biologists, and in this it succeeds, although one might think that some accuracy has been sacrificed as a result. Conversely, the sections on gene regulation are quite detailed and would be hard to follow without a certain amount of background—again, suitable for readers coming from a biological background. Readers of Systematic Biology might also note that, despite the fairly constant references to phylogeny, the book could have been sharpened by more rigorous attention to what phylogenies actually tell us.

REFERENCES


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Phylogenomics as a separate field was named 15 years ago (Eisen 1998) and appears to be growing exponentially, judging from the number of publication titles containing the term: 27 between 2001 and 2005, 89 between 2006 and 2010, and 76 from 2010 to the middle of 2013 (Web of Science search on 5 July 2013). Phylogenomics covers the intersection of molecular biology and evolution, or perhaps more precisely, phylogenetics and genomics (Eisen and Fraser 2003). We are aware of only one other attempt at a textbook prior to Phylogenomics: A Primer, namely the collection of protocols and resources compiled by Murphy (2008). The primer now offered by Rob DeSalle and Jeffrey Rosenfeld is timely and probably eagerly awaited by many professors under pressure to offer courses in phylogenomics. This, at least, was our case.

The book is, according to the authors, intended for “advanced undergraduate students and graduate students in molecular biology, comparative biology, evolution, genomics, biodiversity, and informatics.” These students may enjoy the easy writing style, and with guidance they will benefit from parts of this primer. However, this is not the introduction to the research questions, approaches, and tools of phylogenomics we were hoping for. There is too much phylogeography and too little genomics.

The first chapter of Phylogenomics starts with a description of the increasing role of bioinformatics in the analysis of DNA data, a half page on microarrays (followed by a long table on microarray data that has no apparent connection to anything), a paragraph on the human genome project, and sections on non-parametric statistical analyses, maximum-likelihood analyses, and Bayesian analyses. All of this is without citations or references to later sections of the book, where these topics are taken up in more depth. Here and throughout, there is frequent name-dropping without any indication about why a person’s work is brought up, when it was done, or how it relates to phylogenomics. Typical examples are: “This is the basis of science; as Immanuel Kant stated, ‘Science is organized knowledge’” (p. 11; this appears to be a confusion with the philosopher Ernst Cassirer); “Recently the entire genomes of Dr Craig Venter and Dr James Watson have been sequenced by using only a fraction of the time and cost expended in the initial human genome projects” (p. 24; there is nothing before or after this sentence about these doctors); and “Interestingly, Charles Darwin and Gregor Mendel lived around the same time, and if communication at the time had been more extensive, then each would have known about the other’s theories and a quicker synthesis of genetics and evolution might have occurred” (p. 36). Actually, communication in Old Europe was not what held things back. Mendel studied The Origin of Species in a German translation of 1863, and in his personal copy he made many notes in the margin. Conversely, Darwin had several opportunities to read Mendel or Mendel’s results, but seems to have shied away from the mathematical annotations (Galton 2009). We doubt that students will benefit from such haphazard stewing in of the history of biology, especially without mention of years or even relevant centuries.

Chapter 2 covers the structure of DNA, the codon code, protein folding, next-generation sequencing, and microarrays, all in a cursory manner. Chapter 3 covers microevolution, macroevolution, species concepts, and