The Cambrian explosion and eye evolution solved at one stroke

In the Blink of an Eye.
by Andrew Parker.
Perseus Publishing, 2003, 316 pp.
(many black/white illustrations and color photographs,
no references/notes).

reviewed *by* Gert Korthof. 22 June 2003

In this book, Parker describes his solution for the famous Cambrian explosion. What is the Cambrian explosion and why is it a problem? The Cambrian explosion is the fact that 543 million of years ago there were 3 animal phyla and 538 million of years ago there were 38 animal phyla. So in 5 million years 35 phyla originated. Darwin already recognised this as a problem for his theory of gradual evolution. It seems too fast for gradual evolution. Religious critics routinely use it as an argument against evolution. But even some non-religious critics use it to refute gradual evolution. Critics often distort and exaggerate the problem, but hardly study it. There are several good popular science books describing the Cambrian Explosion, but Parker is the first who describes it and solves it.

Internal and external

Parker introduces an important distinction between internal and external characteristics of organisms:

internal characteristics:

- internal organisation, development
- unique for animal phyla
- many genes (copious genes)
- "internal body plans cannot be built up gradually because usually they can't function in intermediate stages."; "there can be no intermediate stages in body plan"; internal body plans cannot be constructed stepwise and so are less influenced by the environment; 38 phyla are caused by '38 monumental genetic events'
- no convergence of internal body plans

external characteristics:

- external shapes (shell,spine,arms,eyes,colours), outer layers
- considerable fewer genes *)
- associated with environment, adapted
- convergence is possible
- accumulation of point mutations
- intermediate stages provide some advantage

*) but sometimes at least 6 subsystems must be in place (p.93).

The Cambrian explosion

Having explained the differences between internal and external body parts, Parker states: "The Cambrian explosion is all about external body parts only". Evolution of hard external parts took place simultaneously in all phyla after a considerable period [120 million of years ago] during with nothing happened. "Now we know that the Cambrian explosion was the spontaneous evolution of external body parts in all phyla, where the internal body plans of all phyla are already in place." This is beautifully illustrated on pages 38,39 (one illustration tells us more than thousands words!). So what Parker does is in fact split up the Cambrian problem in two separate problems and focuses in the rest of his book on the second part. The first part, the evolution of internal body plans, is the most difficult one in terms of Darwinian processes because of the lack of viable intermediates (in Parker's view).

The solution: Light Switch theory

Parker's Light Switch theory is based on the fact that organisms at the beginning of the Cambrian had hard parts, while in the Precambrian only soft bodied animals occurred. Palaeontologists interpreted hard parts (shells, spines) as a protection against predators. For example, Simon Conway Morris concluded that "one of our principal conclusions is that the role of predation was very important and had at least one direct feedback: the promotion of protective skeletons." (1). Parker adds predators with eyes. That is a very important addition to the explanation. It was a missing piece of the puzzle. The crucial evolutionary step was the development of eyes in predators. This is the Light Switch theory. The development of eyes in predators triggered the evolution of hard parts in prey. It must have been paradise for the first predators: soft bodied animals swimming all around: a free breakfast, a free lunch and a free dinner. No soft-bodied animal could escape from predators with eyes. Independent of this, Parker found that many organisms at the start of the Cambrian were obsessed with colour. They were colourful. He managed to reconstruct the original colours of fossils. Since colours are costly, they must have a function. That means colours were intended for eyes. I find this the most convincing part of Parker's Light Switch theory: "from the beginning of the Cambrian up to today, the world has been adapted to predators with vision." It neatly connects palaeontological observations with evolutionary theory and ecology, especially coevolution of prey and predator (evolutionary arms race).

Timing

The timing of the events (543 million years ago) that makes Parker's Light Switch theory an explanation of the Cambrian explosion (in Parker's definition). The eye

did suddenly appear at the beginning of the Cambrian and it instantly became a common characteristic. The first eye on earth (compound eye) appeared in a Trilobite at the very beginning of the Cambrian, around 543 million years ago. It was a sophisticated designed eye. Not a single species of Trilobite before that time had eyes! (although light-sensitive patches existed for a long time). Thus 544 million years ago there were no eyes on earth.

Completeness

According to Parker, the appearance of eyes was the biggest change in the environment of all. Vision affects all animals unlike other senses. Only six of the 38 phyla today have eyes, but >95% of all animal species have eyes and 32 phyla did not evolve eyes in the Cambrian. Although this looks like a discrepancy or an incompleteness of his theory, the 95% suggest that eyeless phyla are not species rich, and the successful groups are those with eyes.
It would deepen our insight in the advantages and disadvantages of eyes, to learn which species can live without the benefit of eyes in the presence of predators with eyes. Why are there still blind marine animals (sea cucumber, starfish)? How can some be colourful? Do blind colourful predators exist? How could trilobites without eyes exist at all? What alternative lifestyles are available? Forget about eyes and produce toxins?

Specificity

Parker's theory needs a reason that makes the evolution of the eyes faster than that of the other senses (hearing, taste, smell, touch). According to Parker, other senses show a gradual increase in performance during geological time, whereas the evolution of the eye is a nearly instantaneous process. Therefore, the evolution of the eye is the most important factor in the Cambrian explosion.

Adequacy

Now the Cambrian explosion, a process so fast that it was called an explosion, is explained by the sudden evolution of eyes. It seems that sudden evolution is explained by sudden evolution. How fast can eyes evolve? Can evolution produce eyes in one million years? Parker invokes Nilsson and Pelger (2) to deliver the answer. A camera-type eye can evolve from light sensitive cells in 364,000 generations. If there is one generation per year, the evolution of an eye is theoretically possible within half a million years. Now that really is 'In the Blink of an Eye' (book title!). That is a pessimistic estimate. It could be faster if selection pressure was higher or the steps bigger. Parker further points out how the nerves and the brain of the animal could have evolved the capacity to do something with the newly acquired visual information. The theoretical time calculated for the evolution of the eye fits neatly in what palaeontology tells us: between 544 and 543 million years ago. So it seems Parker has a solution for two old Darwinian enigmas: the evolution of the eye and the Cambrian explosion at one stroke.

Intermediates

Parker did not emphasise one condition and that is each step in the evolution of an eye must be advantageous to be positively selected. If neutral or disadvantageous

steps are involved, the evolution of the eye fails. Remarkably, Parker forgets the importance of this condition when he argues for the unparalleled speed of the evolution of eyes, when compared with that of other senses (smell, taste, touch, hearing). "The evolution of receptors for stimuli other than vision can theoretically show a linear progression, but a light perceiver with an inadequate lens has little advantage over one with no lens." (p. 284). This seems to imply that only big jumps (saltationism) or an unknown non-Darwinian process (a miracle?) could produce eyes. However, the whole point of Nilsson and Pelger was that all intermediates are useful and 'a little advantage' does drive the process forward. Consequently, there are no insurmountable obstacles on the road to the eye. Furthermore, if Parker accepts half a million years for the evolution of eyes, then necessarily only intermediates existed during that period. Intermediate eyes could not survive for such a long period if they did not have a selective advantage. Clearly, a fast process does not require that intermediate eyes are useless. A fast process could be caused by huge benefits. Parker himself pointed out those benefits: better predation. I think Parker is still right about the specificity of the eye factor because of the huge benefits of eyes.

Handicap principle

Parker remarks about courtship of the notched seed-shrimp: 'it had to be really efficient to outweigh the disadvantages inherent in making oneself so conspicuous to predators'. This is 'The Handicap Principle' in short (Parker does not mention it by name). There is a beautiful and popular exposition of the Handicap Principle in the book of Zahavi and Zahavi (3). It is supported by an increasing amount of evidence. Remarkably, Parker denies that it applies to birds, because they can escape predators by flying away! His example, the peacock, is certainly handicapped by his long and heavy tail. The peacock is an outspoken example of the Handicap Principle.

Questions

A few questions remain. Nilsson's calculations are about phenotypes (optics of an eye) and need to be supplemented by genetic data. How many genes are involved in the construction of a light sensitive cell and a camera-type eye? How many and which mutations are necessary to transform one into the other? It seems possible to design experiments to test the hypothesis that imperfect eyes have an advantage.

Light-sensitive cells existed for 100 million years before the Cambrian explosion without producing camera-type eyes. Why the delay? This delay in combination with the sudden appearance of eyes is the next problem any Cambrian explosion hypothesis needs to solve.

Another question is, how did the basic body plans arise? If internal body plans cannot be built up gradually, as Parker claims, then how? What does Parker mean by '38 monumental genetic events'? Parker writes a lot about palaeontology, optics and marine ecology, but not much about genomics and evo-devo. However, neither palaeontologists nor evolutionary biologists can solve evolutionary problems in isolation. They need to work together. Evo-devo seems promising in this respect (4).

Whatever questions remain and whatever their importance, one cannot reasonably demand from the inventor of a new hypothesis that he solves all the remaining problems in evolutionary biology. There is always a next problem lurking around the corner.

Parker's hypothesis does more than solving an old palaeontological problem. His Light Switch hypothesis is an eye-opener. It throws light upon all creatures swimming or crawling in the depths of the sea. When I see an exotic marine predator in another episode of "Built for the kill", I now ask questions, I never asked before: do prey and predator have eyes, light sensitive cells or are they blind? Do they have eye-catching colours? By the way, "Built for the kill" is certainly misleading because, for every species built for the kill, we need a species "Built for the escape".

References

1. Simon Conway Morris(1998) "The Crucible of Creation. The Burgess Shale and the Rise of Animals", pp.159-163.
2. Nilsson and Pelger(1994) "A pessimistic estimate of the time required for an eye to evolve", Proc Roy Soc London,B,256,53-8. (I added this one because there are no notes and references in Parker's book).
3. Zahavi & Zahavi(1999) "The Handicap Principle. A Missing Piece of Darwin's Puzzle.", Oxford University Press paperback.
4. "The Origin of Animal Body Plans. A study in Evolutionary Developmental Biology" on this site.

Links

-  Email from Andrew Parker on the Feedback page of this site.
- A hostile review of the book by Simon Conway Morris On the First Day, God Said... in the American Scientist online (July-August 2003). It seems unnecessary harsh criticism to me.

Further Reading

- Andrew Knoll (2003) *Life on a Young Planet: The First Three Billion Years of Evolution on Earth*, Princeton University Press.
  Knoll believes that the rise of oxygen fuelled the Cambrian explosion. Reviewed in *Nature* **423**, 481-482(2003) 29 May 2003 and in Science 15 Aug 2003.
- James W. Valentine (2004) *On the Origin of Phyla*, University of Chicago Press.
  This book is about the Cambrian explosion, but contains little about ecology and almost nothing about the physical environment, according to reviewer Stephan Bengtson in *Nature* **430**, 506 (29 July 2004). The book is also reviewed in *Science*, Vol 305, issue 5684, 613-614, 30 July 2004 by Andrew Cameron: 'Hunting for Origins': "*On the Origin of Phyla* is a likely candidate for the bookshelves of those who hunt for pre-Cambrian fossils or the historical patterns in DNA sequences".
- Andrew Parker (2006) *Seven deadly colours* paperback edition (with b&w illustrations and color plates). This is the second in a trilogy of which *In the Blink of an Eye* was the first. Why do kestrels hover over motorway verges, where their prey is well camouflaged? Why is the harmless Malayan Eggfly butterfly so spectacularly conspicuous, when its predators are birds with good vision? Why do some parrot feathers appear bright yellow to us when they are lit by ultraviolet light only? Why are red, oar-footed shrimps seen by some predators in the deep sea, where light is known to be only blue?

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