The Mystery of Trilobite Evolution

Jerry Bergman*

Abstract

One of the most ancient of all known fossils is the trilobite. Fortunately, a large number of well-preserved examples exist that allow a detailed study of this complex animal. As a result, much is known about it, including its external morphology and even its advanced, well-designed, complex eye. Research on the trilobite eye shows that it is far more complex and better designed than thought, even just a few years ago. This paper concludes that no evidence exists in the fossil record for trilobite evolution from lower forms of life and that the first trilobite was unequivocally a trilobite.

Introduction

Trilobita is a large class of extinct marine arthropods that were very abundant in both the Cambrian and Ordovician periods of history, with a range extending up into the Permian. They are believed by evolutionists to have flourished between about 250 and 521 million years ago (Schaefer, 2001). The trilobite fossil record extends all the way back to the lower Cambrian and possibly even the Precambrian (Waggner, 1999). Trilobite fossils are also so numerous that they are now one of the best known and documented extinct arthropods (Hartmann, 2007). They are also, by far, the most diverse of all extinct arthropods—so far, about 20,541 species, over 5,000 genera, and 165 families have been identified (Rábano and Gozalo, 2008). Most trilobitologists believe that, ecologically, trilobite habitats ranged from reefs to deep-water bottoms, and evidence exists as well that some were very efficient swimmers.

The enormous number of well-preserved trilobite fossils uncovered so far has allowed a detailed study of the animal's history and anatomy. Due to "unusually good fossil preservation," scholars also "know a good deal about the anatomy of the softer parts of trilobites," including their internal organs (Waggner, 1999, p. 1288). For all of these reasons trilobites are an excellent life-form to investigate the validity of macroevolution (Fortey and Owens, 1990).

Trilobite Evolution

The thousands of trilobite fossils uncovered in the past two centuries have yet to reveal evidence for a step-by-step evolution of more "primitive" ancestors leading up to the first trilobite. No evolutionary history exists for the first trilobites, when such evidence should be abundant due to the preservation quality of the hard trilobite shell, its commonality in the ancient world, and its abundant, well-preserved fossil record. Instead, what is found is enormous morphological variation *after* they appear in the fossil record. As two trilobite experts have opined:

> The introduction of a variety of organisms in the early Cambrian, including such complex forms of the arthropods as the trilobites, is surprising ... The introduction of abundant [trilobite] organisms in the record would not be so surprising if they were simple. Why should such complex organic forms be in rocks about six hundred million years old and be absent or unrecognized in the

* Jerry Bergman, Ph.D., Biology Department, Northwest State College, jbergman@northweststate.edu

Accepted for publication August 26, 2009

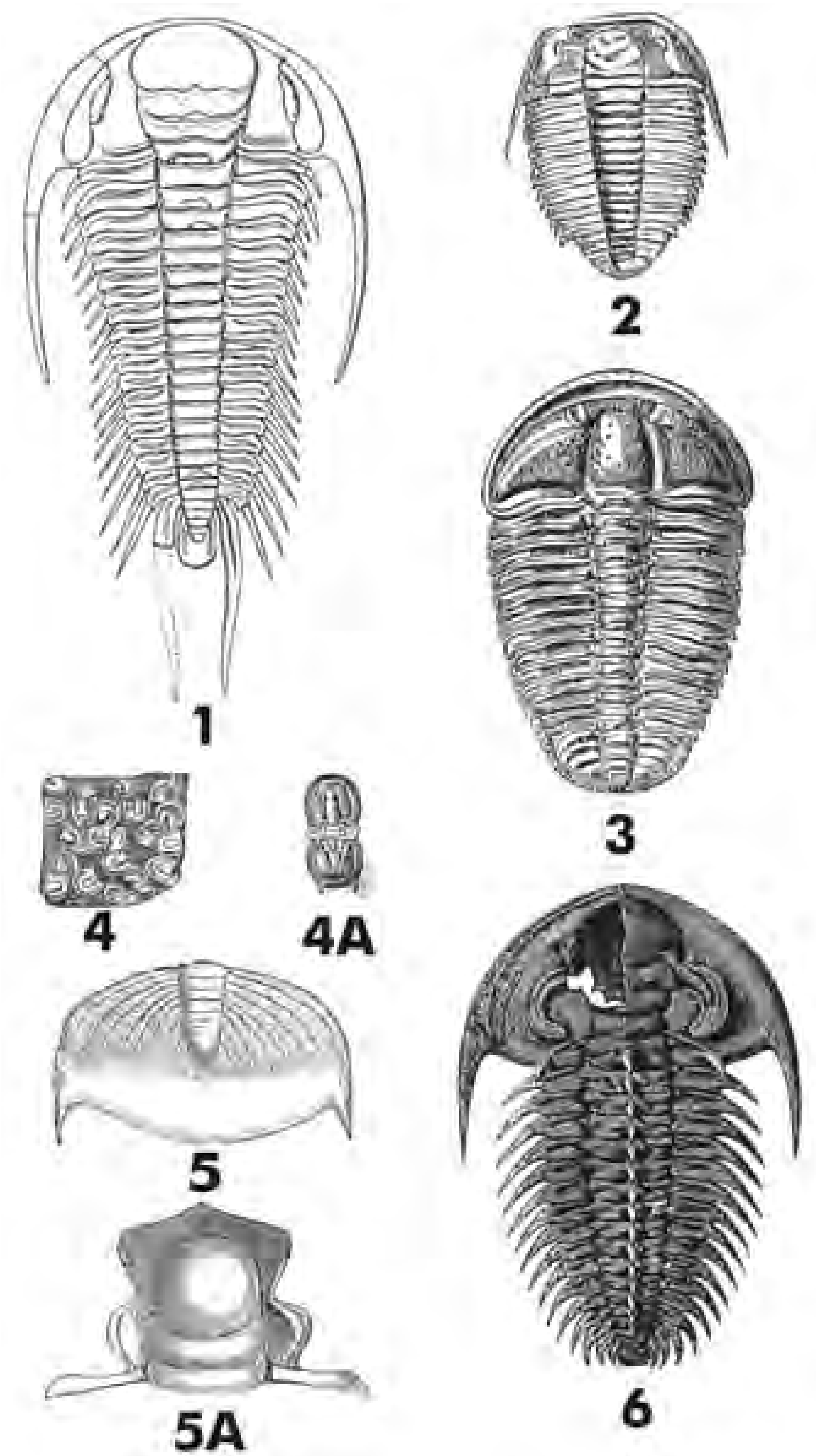

Figure 1. A selection of Cambrian trilobites showing their variety (1, 2, 3, 6), their common group assembly in the fossil record (4), an individual trilobite taken from 4 (4a), the trilobite tail shield (5), and the central part of a trilobite head (5a). Adapted from Kayser and Lake (1893).

> records of the preceding two billion years? If organisms evolved, it should have taken a long time for them to have developed into forms such as the arthropods … If there has been evolution of life, the absence of the requisite fossils in the rocks older than the Cambrian is puzzling. (Kay and Colbert, 1965, pp. 102–103)

Others have concluded that "the variety and structural complexity of trilobites found near the base of Cambrian rocks surely indicates a very long antecedent existence of animal life … No one has thus far been able to discover any fossil evidence to support this required long antecedent existence" (Moore et al., 1952, p. 475). Furthermore, the trilobite "fossil record shows … new species with the new characters appearing abruptly in the early Ordovician" (Whittington, 1992, p. 90). Debate exists not only on trilobite origins but even over how they should be classified (Waggner, 1999).

Unequivocal evidence of trilobites does not appear in the fossil record until the Mid-Lower Cambrian. The Cambrian is divided into four series and ten stages, and trilobites appear below the beginning of series 2, stage 4. Thus, by evolutionary timetables, an estimated 21 million years of evolution are completely missing between the Precambrian-Cambrian boundary and the first recorded appearances of the Trilobita.

Evolutionists have faith that someday evidence for trilobite origins will be uncovered that explains the "abrupt appearance" problem, assuming that trilobite evolution occurred so rapidly that the likelihood of fossilization was small (Whittington, 1992, p. 90). This unsupported a priori conclusion assumes evolutionary theory in spite of the missing (but nonetheless required) evidence. Absent evidence is not positive evidence, and, considering the fact that an estimated 5,000 genera exist, this indicates that billions of transitional fossils must have once existed, and at least a few thousand clear examples should

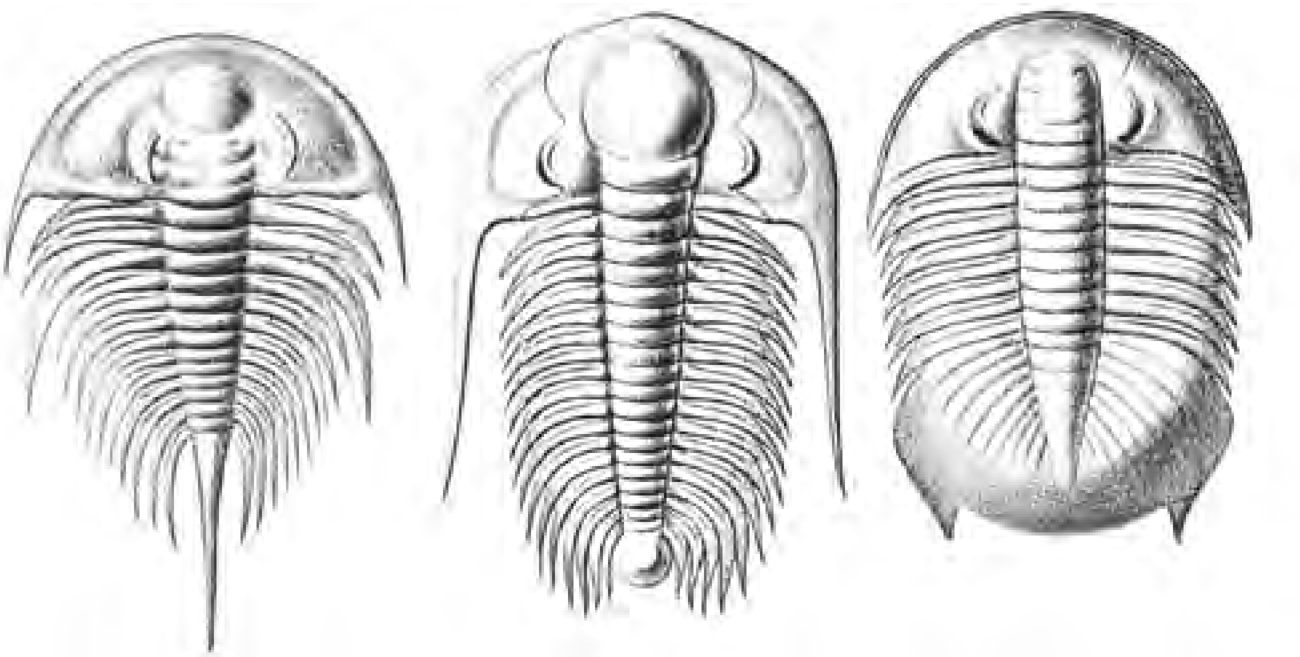

Figure 2. Three examples of Cambrian trilobites illustrating some of the enormous variety typical of trilobites. From Cleland (1925, p. 412). The author claims that "in nearly every particular they were very primitive or simple in structure" (pp. 412–413). It is now known that this is not true. The trilobite eye is the first known eye and is as advanced as many of the most modern eyes known. See text for details.

have been preserved in the fossil record. Gon (2007) noted:

> Some remarkable sites such as Chengjiang, Kaili, and the Burgess Shale reveal the rich diversity of non-calcified arachnomorph arthropods. The fossils of the Precambrian reveal some bilaterian diversity, among them a few species that *might be* candidates for trilobite ancestors. (p. 1, emphasis added)

These possible candidates were not selected on the basis of evidence, but because no other fossils are even plausible. Not only is the absence of trilobite ancestors "puzzling," but trilobite origins remains "cryptic" (Fortey et al., 1996) and assumes a "prior evolutionary history of which we know nothing" (Lipps and Signor, 1992, p. 345). Yet, evolutionists argue that trilobites "must have" somehow evolved from an as-of-yet-unknown ancestor. The stratigraphic sequence "does not present an unequivocal narrative of early trilobite evolution, and there *must have been* events in that evolution of which we have no record in the rocks" (Lipps and Signor, 1992, p. 345, emphasis added).

Actually, the trilobite is one of several thousand life-forms that suddenly appeared in the fossil record almost concurrently *with no trace of any ancestors*. Add to this the fact that field observations by trilobite specialists reveal stasis (i.e., little or no change) within the various trilobite species once they appeared in the fossil record (Eldredge, 1985). In one detailed study of trilobites, Eldredge concluded, "The most amazing feature of the entire *Phacops rana* [trilobite] story is its stasis—a persistence against change—through vast amount of time" (1972, p. 59). This problem is explained by Eldredge and Eldredge (1972) as follows:

> The fossil record is full of apparently sudden evolutionary jumps, where a parent species is followed by its daughter species without intermediate fossil links connecting the two. The traditional explanation for such jumps is an incomplete fossil record, but our findings contradict tradition. (p. 53)

Their solution to this problem is to suggest that:

> When conditions permitted, animals that had evolved far away and thousands, if not millions, of years previously, migrated to territories formerly occupied by their ancestors. The sudden jump effect in any one locality actually reflects the sudden appearance of a migrant that had already evolved elsewhere (Eldredge and Eldredge, 1972, p. 53).

The problem with this explanation is that no evidence exists *anywhere* for trilobite evolution from lower forms of life. It is significant that much evidence exists for small adaptive changes within

Figure 3. An unusual trilobite that contains prominent eyestalks. Picture courtesy of David Lines and Creation Evidence Museum.

the Trilobita, but none for its putative ancestors. For this reason migration does not explain their sudden appearance in the fossil record. Another problem is that the wide "diversity of fossil trilobites poses a challenge to traditional evolutionary theory" (Eldredge, 1980, p. 47) because no evidence exists that they evolved elsewhere.

Eldredge (1980, 1985) also tried to explain the origin of Trilobita and the whole problem of a lack of transitional fossils by a theory he and Stephen Jay Gould developed called *punctuated equilibrium*. This theory says that while stasis (stability) is the norm in animal history, it is interrupted by rapid evolution, evolution so rapid that no fossil record has been left today. The problem with this idea is that the theory is not based on evidence but rather on the lack of evidence. Eldredge and others (e.g., Gould, 2002) have documented microevolutionary change within the Trilobita, but no one has been able to document either a trilobite ancestor or descendent.

One evolutionary change noted in the fossil record is that Cambrian trilobites display much variability, and later, in the Ordovician, trilobites display *much less* variability, the opposite of that predicted by Darwinian evolution (Hunt, 2007). The trilobites were very abundant in the Cambrian (217 families) and the Ordovician (149 families), but by the Silurian only 44 trilobite families remained because many trilobite families had gone, or were going, extinct. Why they became extinct is unknown, although many theories have been proposed.

The Trilobite Eye

The trilobite eye has been the focus of much research because trilobites possessed the first known "compound" (multi-lensed) eye design type (specifically the diopter apparatus) that has been preserved in detail in the fossil record. Marine biologist Richard Ellis called the compound trilobite eye, a system containing hundreds of lenses, "far more complicated than the eyes of any vertebrates" (Ellis, 2001, p. 7). Paleontologists claim that the trilobite not only had "highly organized visual organs, but some of the recently discovered properties of trilobites' eye lenses represent an all-time feat of function optimization ... a very successful scheme of eye structure: the composite or compound eye" (Levi-Setti, 1993, p. 29).

Although the trilobite eye is the oldest eye of which we have fossil evidence (Sinclair, 1985, p. 9), the once misnamed "simple primitive" trilobite eye is now known to be an incredibly well-designed, complex optical-chemical system. A half-century ago Duke-Elder (1958, pp. 156–157) wrote that a major problem in proving the evolution of vision is that in "the earliest fossils known to man—the Trilobites ... both median ocelli and lateral compound eyes are present which have reached a high stage of complexity."

Based on careful fossil study, researchers have concluded that trilobites could see exceptionally well, even though they often lived in the very deep (thus, very dark) sea bottom. One reason why is because the trilobite eye lens was designed specifically to function in low-light water environments. To do this, trilobites "possessed the most sophisticated eye lenses ever produced," and their vision may actually have been superior to modern living animals (Shawver, 1974, p. 72).

A compound eye is constructed from a large array of separate eye optical elements called *ommatidia*. Each ommatidia was pointed in a different direction to allow the trilobite to simultaneously see in front, on each side, and behind, giving it a panoramic view of the world (Fortey et al., 2004). A network of neurons then translated the many optical images picked up by the compound eye photoreceptors into a single composite picture. Evidence of the effectiveness of this eye design is the fact that it is still widely used today by both insects and crustaceans (Levi-Setti, 1993).

The Trilobite Eye Lens

The eye lens used on each ommatidium is another example of the excellent trilobite design (Fernald, 1997, 2001). The corneal lens was constructed out of clear calcite crystals, a hard mineral with very unique optical properties well suited for underwater vision. The trilobite calcite lens is unique in the entire animal kingdom—most eye lenses are the "soft" type constructed out of cuticle (Fortey et al., 2000, p. 92). The trilobite design employed two separate layers called a *doublet*, each with different optical properties that functioned together as a unit to focus the image.

Trilobite eyes were usually hexagon shaped, but some used square, elongated clear calcite prisms (Fortey et al., 2000). The result was a design that had a huge advantage in low light, even compared to most highly developed eyes of living animals. The lens used the spherical aplanatic design that largely eliminated the spherical aberration problem, the distortion caused by the lens shape (Fortey et al., 2004). Spherical distortion causes the image to lose sharpness and become slightly distorted—especially at the lens periphery compared to the lens center.)

> This optical doublet is a device so typically associated with human invention that its discovery in trilobites comes as something of a shock. The realization that trilobites developed and used such devices half a billion years ago makes the shock even greater. And a final discovery—that the refracting interface between the two lens elements in a trilobite's eye was designed in accordance with optical constructions worked out by Descartes and Huygens in the mid-seventeenth century—borders on sheer science fiction. (Levi-Setti, 1993, p. 54)

The Three Basic Trilobite Eye Designs

A large amount of variety exists in both the body and the eye design of

Figure 4. An example of an unidentified trilobite still largely embedded in rock, showing the challenge of removing them from solid rock. It is partly rolled up in a ball and appears to have been forced into the mud. Picture courtesy of David Lines and Creation Evidence Museum.

the estimated 5,000 different trilobite genera. For example, specific trilobite eye design varied according to the light environment in which the trilobite lived (Clarkson, 1975). Some trilobites were equipped with eyes that used a few lenses; others had eyes with lenses numbering in the thousands. Some eyes took up most of the cephalic surface, and others were fairly small. The most common eye design was a turret shape that produced a combined visual field able to survey the animal's entire surroundings (Levi-Setti, 1993).

Three basic designs exist: the *holochroal*, the *schizochroal*, and the *abathochroal*. The *holochroal* variety was both the most common and the most complex trilobite eye design. This design consisted of thousands of small hexagonal-shaped lenses that functioned together as a unit. Each lens used a shelled, biconvex design consisting of a thin calcite lamellae covered by a protective film. This design, utilized in all trilobite orders, is found in many different species. Post-Cambrian trilobites, though, tended to have thicker lenses.

The second trilobite eye type, the aggregate or *schizochroal* eye, was similar to the holochroal type except that it had fewer and larger biconvex lenses that were set in a turret-like arrangement, separated by an intrascleral membrane. This "highly sophisticated" eye design is found only in the Phacopida trilobite order and is a "visual system quite different from any other eye that has ever appeared in the animal kingdom" (Levi-Setti, 1993, p. 43; see also Fortey et al., 2004, p. 449). This eye appeared fully formed in the fossil record during the late Cambrian period. The juvenile holochroal eye resembled a schizochroal eye, and Darwinists believe that it was paedomorphically derived—paedomorphosis being the retention of ancestral juvenile characteristics into adulthood (Clarkson, 1975).

The last basic trilobite eye type, the *abathochroal* form, resembled a schizochroal eye, except that it did not have interlensral membranes between individual lenses. This design was utilized in only a few types of Cambrian trilobites.

A few eyeless trilobite species also existed, all of which lived in the darkness of the deep sea floor below the photic (sunlit) zone (Fortey et al., 2004, p. 449). Instead of labeling these trilobites more primitive than sighted trilobites, because lobsters and other crustaceans that live on the deep sea floor are also eyeless, evolutionists speculate that their eyes were slowly lost during evolution. The Darwinist's explanation of the origin of the trilobite eye design is that:

> through natural selection operating on chance variations—trilobites evolved a remarkably sophisticated optical system. For an optical engineer to develop such a system would require considerable knowledge of such things as Fermat's principle, Abbe's sine law, Shell's laws of refraction, the optics of birefringent crystals, and quite a bit of ingenuity. (Stanley and Raup, 1978, p. 182)

Lack of fossil evidence has forced scientists to speculate on the path of trilobite evolution, and lack of evidence for trilobite eye evolution is especially problematic for Darwin's theory. For this reason "views on eye evolution have flip-flopped, alternately favoring one or many origins" (Fernald, 2006, p. 1917). The trilobite eye is the earliest known eye existing in the fossil record, yet it is extremely well designed. It is not primitive but, rather, a highly advanced and very effective eye, especially given the trilobites' typical environment at the bottom of deep water that normally is close to completely dark.

Conclusions

As Whittington notes, trilobites pose two major problems in evolution: the "abrupt appearance of different kinds of trilobites in the Lower Cambrian" and their replacement by new trilobites during the transition from the Cambrian to Ordovician (Whittington, 1992, p. 84). He adds that "no evidence, such as a transitional series of fossils" exists to support trilobite evolution, concluding that there exists "no lack of either interpretation or speculation" (Whittington, 1992, pp. 84–85).

As to why no evidence exists, he stresses only that "what is needed is evidence" (Whittington, 1992, p. 85). Whittington lists a critical appraisal of existing collections, and asserts that a search for new material relevant to these problems from promising sites is a start needed to find the evidence that he believes exists, based on his Darwinist worldview. However, after decades of new fossil discoveries by many researchers, the picture remains the same—no transitional fossils exist for their origins. In short, "trilobites are both complex and diverse when they appear in the lower Cambrian." (Black, 1988, p. 158)

Trilobite eyes, which, as documented in this review, are among the most complex eyes known, appeared abruptly and *very early* in the fossil record. The trilobite eye optics were anything but primitive and would have required an enormous amount of time to evolve, but there are no documented ancestral precursors.

Although trilobite eyes are well preserved and abundant in the fossil record, no evidence exists of their evolution—they appear fully formed in the fossil record. The external similarities of the "primitive" trilobite eye "to those of some modern insects (for example, the ant) is quite remarkable" (Levi-Setti, 1993, p. 34). From similar comparisons the schizochroal eye "probably evolved from the holochroal eye" (Levi-Setti, 1993, p. 34), a conclusion based solely on morphological comparisons, not fossil evidence.

Summary

Trilobites are an "impressive feat of early evolution," but even though they were the most prevalent animal in the Cambrian Sea and an abundant fossil record exists that some conclude dates back to the early Cambrian, no evidence of trilobite evolution from its putative ancestors has yet been uncovered (Shawver, 1974, pp. 72–73). The nonexistent evidence for trilobite evolutionary origins in the fossil record is one factor that motivated Eldredge (1977) to conclude that "to the present day, we paleontologists have managed to contribute relatively little to explicit theories of the evolutionary process" (p. 308). Specifically, trilobite species "tend to remain relatively unchanged … throughout their stratigraphy ranges" (Eldredge, 1977, p. 309).

This is especially true of trilobite eye evolution. The most that scientists can now conclude is that we "have some understanding of how eyes *might* have evolved" (Fernald, 2004, p. 141, emphasis mine). As Levi-Setti (1993, p. 54) concluded, the "real surprise" is not that the trilobite eyes functioned according to the laws of physics, but that their "basic lens designs" were engineered "with such ingenuity." (p. 54). This evidence contradicts Darwin's (1859) prediction that the earliest eyes should be primitive and that a large number of transitional forms proving eye evolution from simple to complex would be found in the fossil record.

Acknowledgments: I wish to thank Jody Allen, Clifford Lillo, and John UpChurch for their comments on an earlier draft of the manuscript

References

Black, R. 1988. *The Elements of Palaeontology,* 2nd Edition. Cambridge University Press, Cambridge, UK.

Clarkson, E.N.K. 1975. The evolution of the eye in trilobites. *Fossils and Strata* 4:7–31.

Cleland, H. 1925. *Geology: Physical and Historical*. American Book Company, New York, NY.

Darwin, C. 1859. *The Origin of Species*. John Murray, London, UK.

Duke-Elder, S. 1958. *System of Ophthalmology, Volume 1: The Eye in Evolution*. Mosby, St. Louis, MO.

Eldredge, N. 1977. Trilobites and Evolutionary Patterns. In Hallman, A. (editor), *Patterns of Evolution*, pp. 306–332. Elsevier, New York, NY.

Eldredge, N. 1980. An extravagance of species. *Natural History* 89:46–51.

Eldredge, N. 1985. *Timeframes*. Princeton University Press, Princeton, NJ.

Eldredge, N., and M. Eldredge. 1972. A trilobite odyssey. *Natural History* 81:53–59.

Ellis, R. 2001. *Aquagenesis: The Origin and Evolution of Life in the Sea*. Viking, New York, NY.

Fernald, R. 1997. The evolution of eyes. *Brain, Behavior and Evolution* 50(4):253–259.

Fernald, R. 2001. The evolution of eyes. *Karger Gazette* 64:1–4.

Fernald, R. 2004. Eyes: variety, development and evolution. *Brain, Behavior and Evolution* 64(3):141–147.

Fernald, R. 2006. Casting a genetic light on the evolution of eyes. *Science* 313:1914–1918.

Fortey, R.A., and R.M. Owens. 1990. Trilobites. In Kenneth J. McNamara (editor), *Evolutionary Trends*, pp. 121–142. The University of Arizona Press, Tucson, AZ.

Fortey, R.A., R.M. Owens, D.E.G. Briggs, and M.A. Wills. 1996. The Cambrian Evolutionary "explosion": decoupling cladogenesis from morphological disparity. *Biological Journal of the Linnaean Society* 57:13–33

Fortey, R.A., R.M. Owens, D.E.G. Briggs, and M.A. Wills. 2000. *Trilobite! Eyewitness to Evolution*. Knopf, New York, NY.

Fortey, R.A., R.M. Owens, D.E.G. Briggs, and M.A. Wills. 2004. The lifestyles of the trilobites: these denizens of the Paleozoic Era seas were surprisingly diverse. *American Scientist* 92:446–453.

Gon, S.M., III. 2007. The question 'where did trilobites come from' is not so simple to answer. Origins of Trilobites. http://www.trilobites.info/origins.htm (as of June 14, 2008).

Gould, S. 2002. *The Structure of Evolutionary Theory*. Harvard University Press, Cambridge, MA.

Hartmann, A. 2007. Rapid evolution in early trilobites fueled by high variation. *Geotimes*. http://www.geotimes.org/july07/article.html?id=WebExtra072707.html (as of September 21, 2009).

Hunt, G. 2007. Variation and early evolution. *Science* 317:459–460.

Kay, M., and E.H. Colbert. 1965. *Stratigraphy and Life History*. Wiley, New York, NY.

Kayser, E., and P. Lake. 1893. *Text Book of Comparative Geology*. Macmillan, New York, NY.

Levi-Setti, R. 1993. *Trilobites*. University of Chicago Press, Chicago, IL.

Lipps, J.H., and P.W. Signor. 1992. *Origin and Early Evolution of the Metazoa*. Springer Press, New York, NY.

Moore, R.C., C.G. Lalicker, and A.G. Fischer. 1952. *Invertebrate Fossils*. McGraw Hill, New York, NY.

Rábano I., and R. Gozalo (editors). 2008. *Advances in Trilobite Research: Proceedings of the* Fourth *International Trilobite Conference*. Toledo, Spain.

Schaefer, L. 2001. *Trilobites*. Richard C. Owen Publishers, Inc., Katonah, NY.

Shawver, L.J. 1974. Trilobite eyes: an impressive feat of early evolution. *Science News* 105:72–73.

Sinclair, S. 1985. *How Animals See*. Facts of Life, New York, NY.

Stanley, S., and D. Raup. 1978. *Principles of Paleontology*, 2nd Edition. W. H. Freeman, San Francisco, CA.

Waggner, B. 1999. Trilobites. In Singer, R. (editor), *Encyclopedia of Paleontology*, pp. 1288–1295. Fitzory Dearborn Publishers, Chicago, IL.

Whittington, H.B. 1992. *Trilobites*. The Boydell Press, Suffolk, UK.