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TECHNICAL COMMENTS

Comment on "A New Species of Yunnanozoan with Implications for Deuterostome Evolution"

As the describers of the original specimens of the Lower Cambrian animal *Haikouella lanceolatum* (*1*–*3*), we read the recent description of new *Haikouella* fossils by Shu *et al*. (*4*) with great interest. The authors interpreted this soft-bodied animal as a stem-group deuterostome, but not as a chordate, whereas we interpret it as the immediate sister group of vertebrates—a chordate that greatly clarifies our understanding of vertebrate origins.

Shu *et al.* (*4*) claimed that *Haikouella* has no chordate-like or vertebrate-like structures, but we have observed many such structures. We suspect that their fossils, though well-preserved in the pharyngeal region, cannot match the overall quality of our best specimens, in which structures down to <10 μm are visible. Some of our specimens show small eyes (Fig. 1, A and B), muscle fibers that indicate the body segments are myomeres (Fig. 1C), a postanal tail (Fig. 1D), a supraintestinal notochord often defined by a dark notochordal sheath (*5*), a low median fin, a big brain, and a thin layer of "skin" rather than a cuticle on the body exterior [most of these features were previously documented in (*2*)]. Many of these chordate structures, which Shu *et al.* could not verify in their material, are in the posterior half of the body—precisely the region where, by their own admission, their *Haikouella* fossils are poorly preserved. The anteriors of their specimens match ours in showing gills and a rostral "skirt" that resembles the upper lips of larval lampreys and of the fossil jawless fish *Haikouichthyes* (*6*).

A positive aspect of (*4*) is that Shu *et al.* documented the three-dimensional preservation of the *Haikouella* fossils, and wisely adopted the name "yunnanozoans" to include both *Haikouella* and the very similar *Yunnanozoan*, which was discovered first. It is also encouraging that their reconstructions of the animals [figure 1K in (*4*)] and ours (Fig. 1) have become much more alike now that they have abandoned their earlier claim (*7*) that yunnanozoans had a proboscis and collar similar to those of modern hemichordate worms, and that the posterior body had a giant dorsal fin.

Shu *et al*. described the gills of their *Haikouella* specimens in detail, but did not mention that gills are confined to vertebrates among deuterostomes, as are a small number of widely spaced pharyngeal arches (*1, 8*) that likewise characterize *Haikouella*. The interpretation of gilled *Haikouella* as a stem deuterostome (*4*) is reasonable only if *Haikouella* is related to the fossil animals called vetulicolians, which Shu *et al*. also consider to be stem deuterostomes, and which may show gills (*9*). However, the phylogenetic position of vetulicolians is highly uncertain because of their thick cuticle and sometimes telescoping posterior body—features of arthropods but not of deuterostomes. Furthermore, in one vetulicolian that was said to have gills (*9*), a long tube extends toward the posterior from each putative gill pouch. No such tubes ever occur in the gill pouches of deuterostomes (vertebrates).

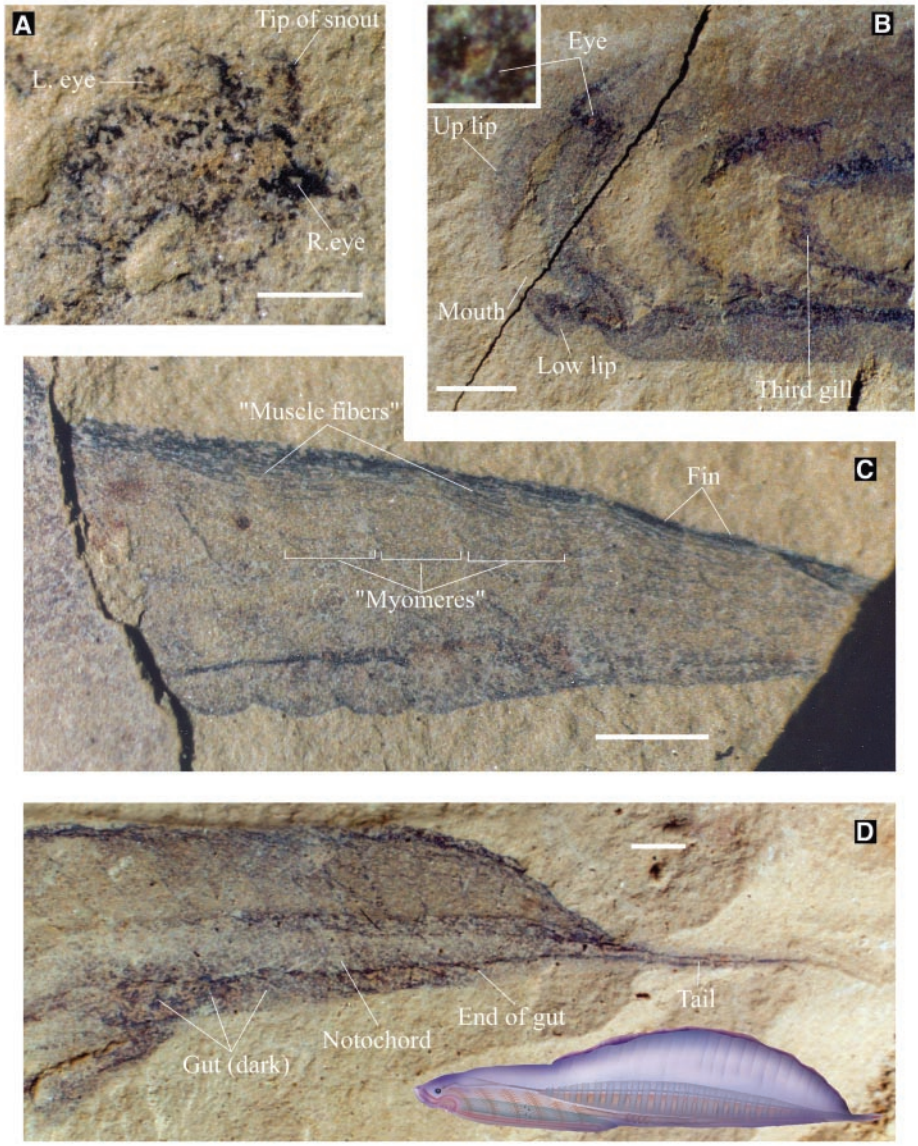

Fig. 1. Previously unpublished photos of *H. lanceolatum*, showing vertebrate characters including eyes, muscle fibers in the myomeres, and a notochord extending into a postanal tail. (**A**) Top of the head, showing both eyes, each surrounded by a dark ring. (**B**) Head and pharynx, with the eye seen as an orange dot surrounded by a black ring (eye enlarged in the inset). (**C**) Trunk, with myomeres and muscle fibers. (**D**) Posterior trunk and tail. (A) is a dorsal view, and (B to D) are left-side views with anterior to the left, as in the cartoon reconstruction of the animal below. [The two other specimens that show eyes are pictured in figures 2 and 7 in (*1*).] Specimens are from the Early Life Research Center in Chengjiang (Jinning), China (*9*): (A), EC00250; (B) EC00100; (C), EC00007b; (D), EC00116. Scale bars are 1 mm long.

Additionally, our observations do not agree with the claim of Shu *et al*. that the pharyngeal arches of *Haikouella* lie exterior to its body. In our specimens, the arches are within the pharynx, internal to a layer of body wall, which can be interpreted as forming an atrium as in cephalochordates. Shu *et al*. also suggested the occurrence of extensive evolutionary changes, such as the transformation of pharyngeal openings into arches, and assumed that the internal gills of vetulicolians and fishes are automatically homologous to perceived external gills in *Haikouella*. These ideas of deuterostome phylogeny, however, may be too complex to stand up to the rigors of a phylogenetic analysis based on parsimony—which should be performed.

Historically, the main objection to the idea that yunnanozoans are chordates has been (*7*) that their body segments extend far dorsal to the notochord, and therefore cannot be myomeres, which lie lateral and ventral to the notochord in chordates. However, our discovery of muscle fibers in these segments confirms that they are indeed chordate myomeres (Fig. 1C). This removes the major hurdle to accepting yunnanozoans as vertebrate-like chordates.

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