Evolution of shell microstructure in Protobranchia (Mollusca: Bivalvia)

Molluscan shells are composed of structural units of calcium carbonate called shell microstructure. Generally shell microstructure is similar among phylogenetically close taxa. Shell microstructural variation also reflects differences in mechanical properties such as shell strength. Hence, shell microstructural architecture has significance in studies on adaptive radiation and macro-/microscopic morphological evolution. This study focusses on protobranchs to clarify evolution of shell microstructures through the origin and diversification of the basal groups of bivalves.

Various shell microstructures were examined through scanning electron microscopy. Furthermore, they were evaluated phylogenetically through molecular phylogenetic analysis using DNA sequences. The resulting ML tree supported the monophyly of four superfamilies of Protobranchia with a major change in the position of the family Sareptidae. Shell microstructures of 38 protobranch species were newly described using scanning electron microscopy. The topology of the obtained phylogenetic tree and shell microstructural composition are consistent at the superfamily level in protobranchs. Shell microstructural grouping found in this study was consistent with the division of higher taxa suggested by molecular phylogenetic analysis. This indicates that shell microstructure of protobranchs reflect their phylogenetic origin. In addition, the descriptions of shell microstructures in previous studies suggest that all ancestral protobranchs had a nacreous structure, although the nacreous structure is never found in the Recent Solemyoidea and Nuculanoidea, suggesting that the shell microstructure of protobranchs evolved from a nacreous to non-nacreous structure, in general. These changes seem to have occurred in the Cenozoic. In synchronization with this event, the distribution of Nuculanoidea shifted to high-latitude and deep-water regions and increased their diversity, probably related to the appearance and divergence of infaunal heterodont bivalves, which occupy a similar habitat. The homogeneous structure, which is dominant in non-nacreous species, is advantageous to the energy cost of shell formation. Therefore, a possible driving force for making advance into such environments is the acquisition of the low-cost shell microstructure.