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Phenotypic evolution, adaptive radiation and ecological speciation in the fossil record: an example from the melanopsids of Lake Pannon

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The mechanisms underlying evolutionary patterns are hard to detect in the fossil record. Often, they are blurred by insufficient preservation, stratigraphic resolution and information about the paleoenvironment. Our investigation on the phenotypic evolution in a gastropod species lineage of Lake Pannon presents a contrasting example of extraordinary preservation and information. In a morphometric approach we analyzed shell outlines and size ranges within the *Melanopsis impressa* lineage across several localities in the Vienna Basin.

A puzzling pattern of morphological evolution is documented over a time interval of 1.6 Ma. This encompasses a broad range of varying modes of evolution. The general trend is a transition from smooth morphologies to highly shouldered and globular phenotypes, including a series of intermediate forms. More precisely, smooth phenotypes prevail over the initial 800 kyr, demonstrating no net change in the morphology, thus reflecting phenotypic stasis. Subsequently, a rapid shift and first expansion of the occupied morphospace is recorded, going along with the appearance of several new, slightly shouldered to globular phenotypes. This is followed by an even more dramatic morphological shift, mirrored in a bifurcation towards two distinct phenotypes. This large morphological variability collapses in the final studied time slice and only a single branch with a small, globular phenotype persists.

All these morphological developments may be related to changes in the paleoenvironment. During the interval of stasis, constant ecological conditions promoted the action of stabilizing selection on the morphological traits. The first shift parallels a massive rise in lake level and hence a change in the availability of habitats. The occurrence of several new phenotypes during this interval is thus considered as an adaptive radiation. The following bifurcation is thought to reflect successively evolving discrepancies of ecological requirements, hence the establishment of isolated ecological niches. Consistent with the model of ecological speciation, the underlying divergent natural selection resulted in reproductive isolation, hence two distinct species. Finally, the subsequent drastic environmental turnover during the Vallesian Crisis wiped out one of these branches together with all intermediate forms; only the small, globular phenotype survived.