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Static, ontogenetic and evolutionary modularity of cranial skeleton in Lacertid lizards

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There is a growing interest for studies of modularity and morphological integration in non-model organisms, and the need for these studies at multiple levels has often been pointed out. Our dataset, consisting of cranium shape data for 14 lizard species from the family Lacertidae, with substantial samples of hatchlings and adults, and their inferred evolutionary relationships, enabled us to perform multi-level assessment of modularity and morphological integration. The skull shape was quantified by landmark based geometric morphometrics, and five alternative modularity hypotheses of lizard cranium were tested using both allometric and non-allometric components of shape variation. At the static level, firm confirmation of cranial modularity was found for hypotheses which separate anterior and posterior functional compartments of the skull. At the ontogenetic and evolutionary level, the hypothesis based on developmental origin of skeletal elements (neurocranial versus dermatocranial) was confirmed. Also, the differences in the pattern of modularity for allometric and non-allometric component of shape variation were found. These results indicate that static modularity could be driven by functional demands and can be regarded as adaptive. The shared pattern of ontogenetic and evolutionary modularity indicates conservativism of modularity patterns driven by developmental constraints. The main implication is that there is a complex interaction of developmental and functional constraints, including allometry, in shaping cranial modularity pattern.