

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



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# Modularity and morphological integration

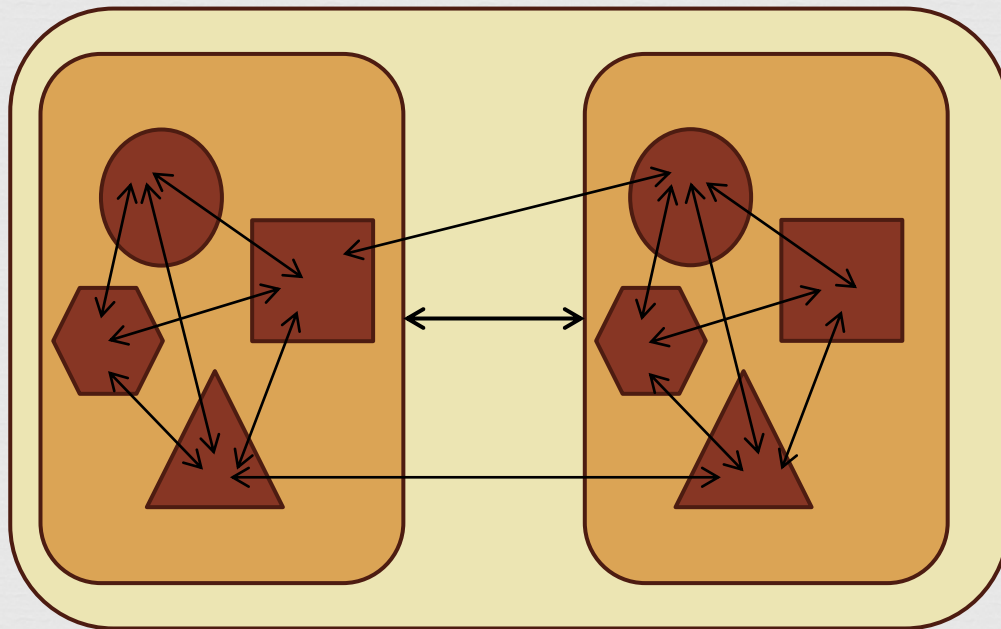
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- ❧ Two interconnected concepts in evolutionary biology.
- ❧ Integration is a tendency of different biological traits to vary in a coordinated manner. Modularity exists if integration is concentrated within certain parts or regions within a structure, i.e. modules.
- ❧ Modularity can also be described as “compartmentalization” of structures.

# Modularity and morphological integration


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Patterns of covariation within and between the modules.

# Modularity and morphological integration

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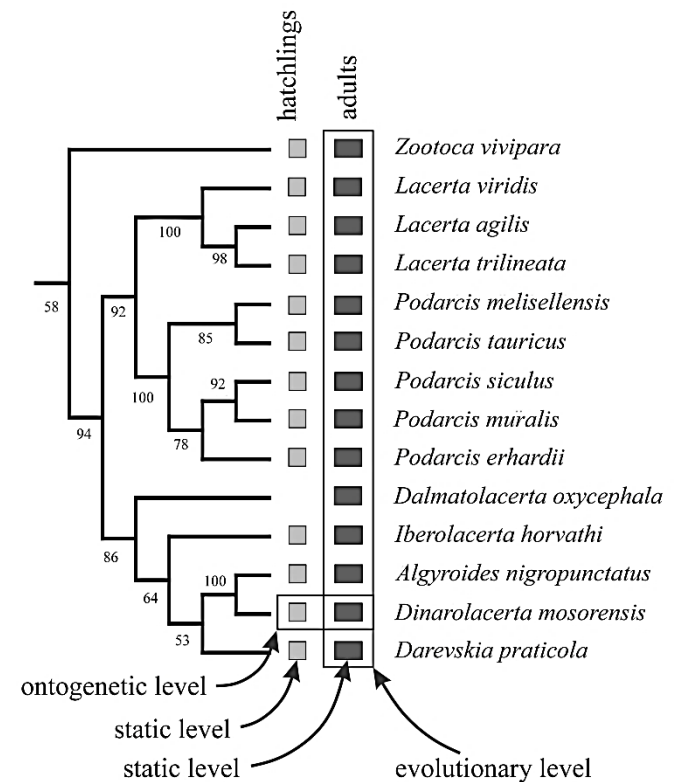


- ❧ Patterns of modularity and integration can be driven by different constraints during pre- and post-natal development. Further, taxa with shared evolutionary history can share patterns of covariation between morphological traits.
- ❧ Consequently, recent studies tend to approach these phenomena at multiple levels:
  - ❧ STATIC – within a single age class of a single taxon
  - ❧ ONTOGENETIC – across ontogenetic stages of a single taxon
  - ❧ EVOLUTIONARY – across the related taxa.

# Studied sample



- 14 species of Lacertid lizards with their inferred evolutionary relationships (760 specimens total).
- Phylogenetic tree published by Pyron et al. (2013).
- Despite possible shortcomings, still a reasonable choice for topology in evolutionary studies on Lacertids.



# Landmarks and hypotheses of modularity



- ☞ We used standard set of landmarks employed in the previous analyses.
- ☞ For the dorsal cranium, hypotheses were formulated according to Sanger et al. (2011)
- ☞ For the ventral cranium, hypotheses were formulated according to the previous studies on Lacertid cranium (Ljubisavljević et al. 2010; Urošević et al. 2013).
- ☞ We did tests for modularity with species and sex pooled-within group – common pattern at the static level.

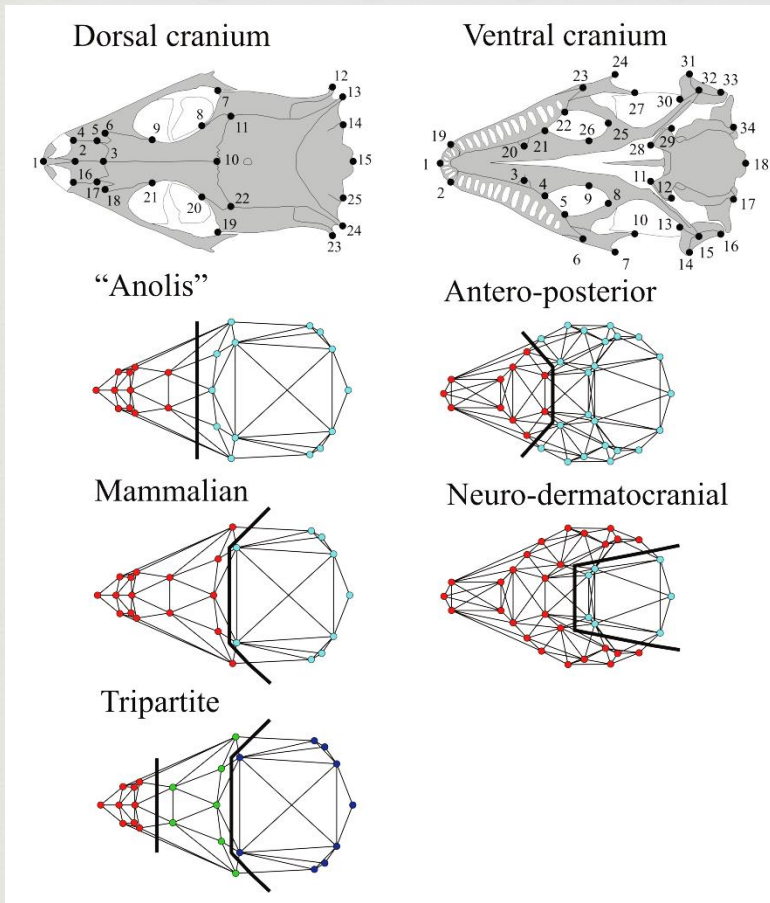


Figure from: Urošević, A., Ljubisavljević, K., Ivanović, A. Multi-level assessment of the Lacertid lizard cranial modularity. Submitted manuscript.

# Phylomorphospaces

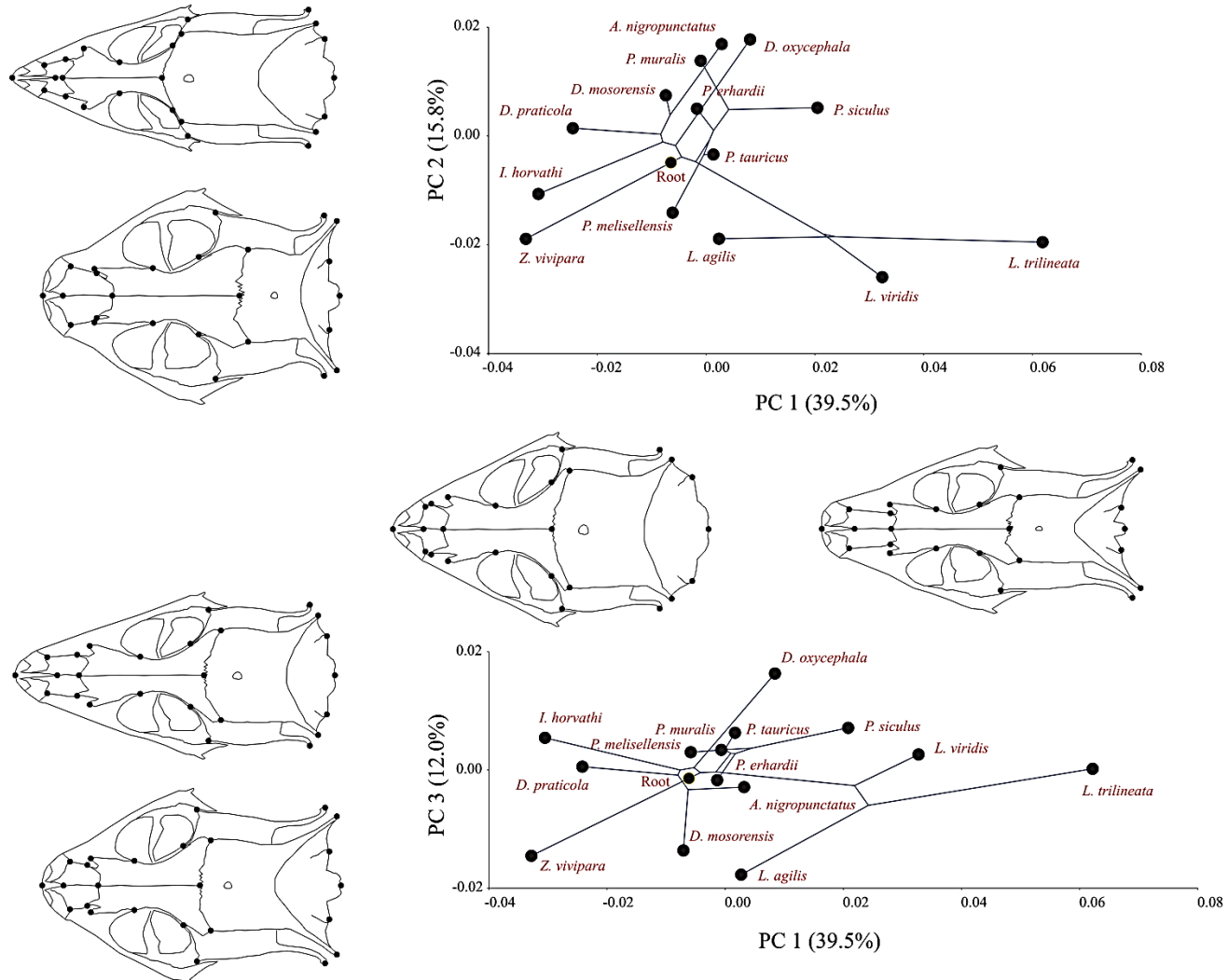


Figure from: Urošević, A., Ljubisavljević, K., Ivanović, A. Multi-level assessment of the Lacertid lizard cranial modularity. Submitted manuscript.

# Phylomorphospaces

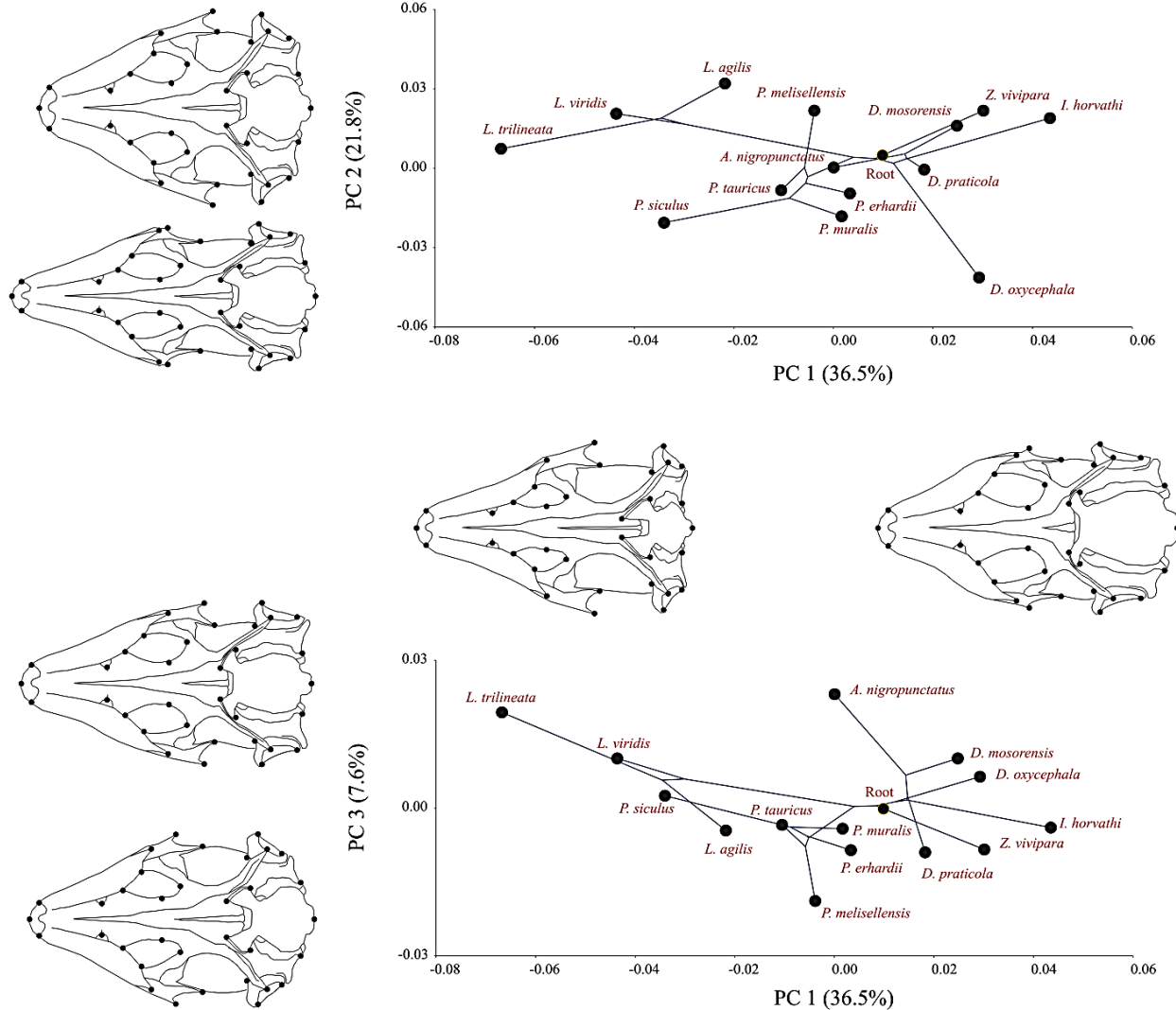


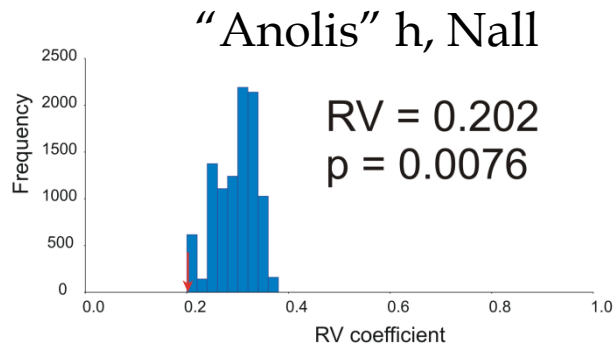
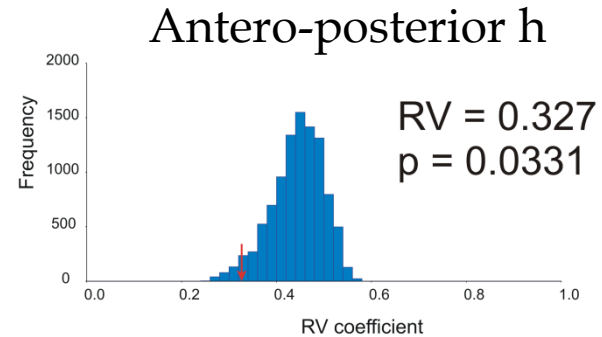
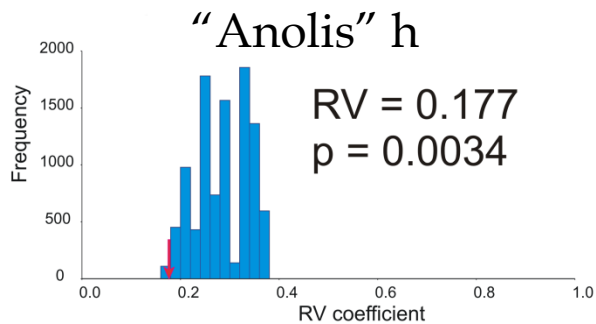
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# Patterns of static modularity



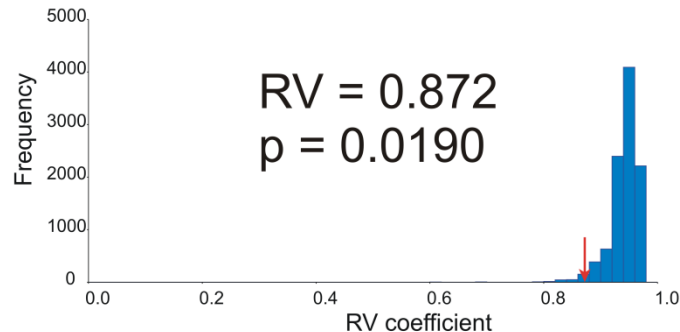
At the static level, the functional hypotheses were confirmed – „Anolis“ and Antero-posterior



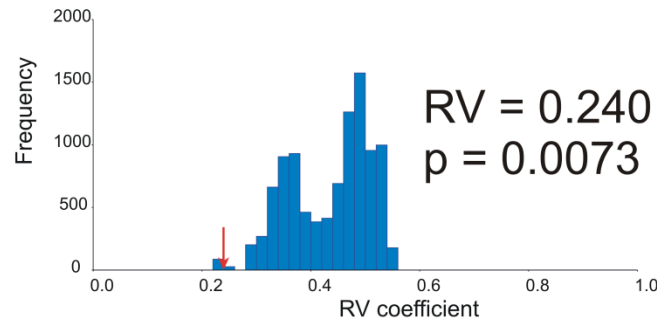
# Patterns of ontogenetic modularity

- At the ontogenetic level, one functional hypothesis was confirmed before and one developmental after size correction.

Antero-posterior h

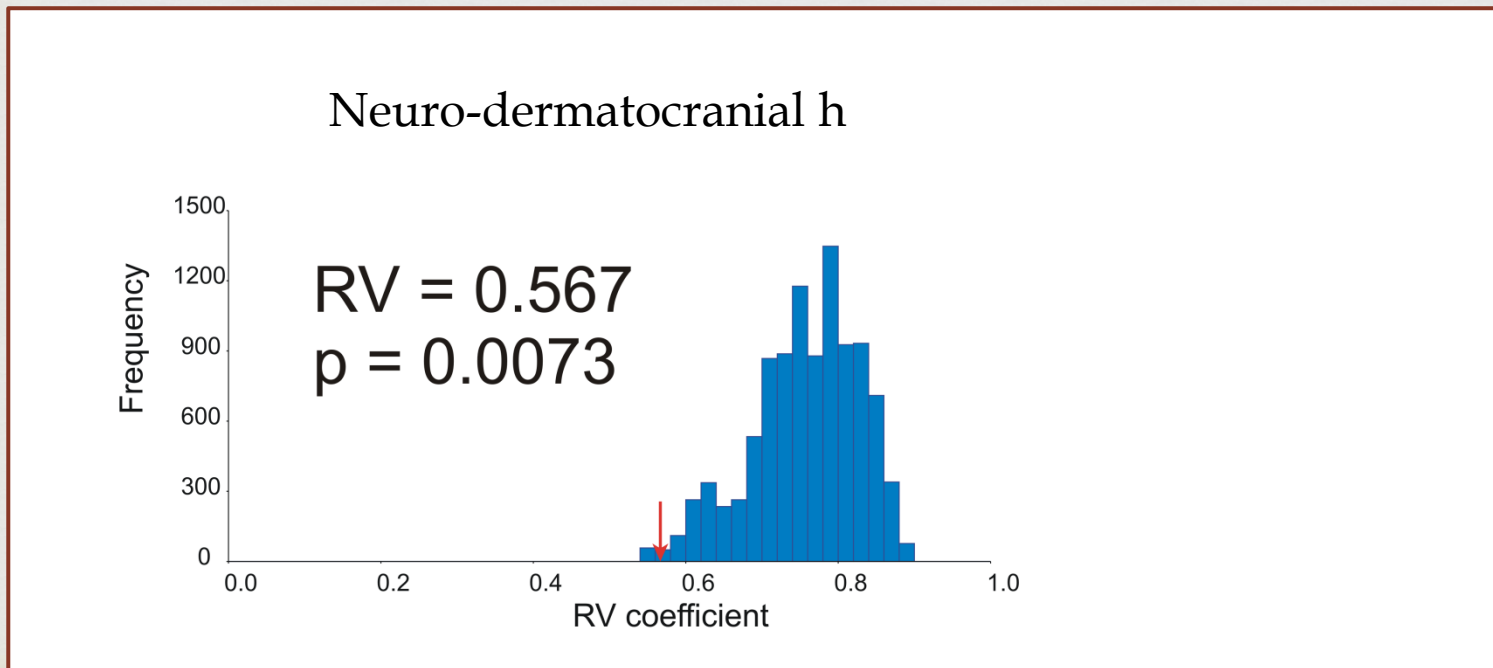


Neuro-dermatocranial h Nall



# Patterns of evolutionary modularity

- At the evolutionary level, the developmental hypothesis was confirmed before size correction.



# Conclusions



- ❧ Static modularity patterns are most likely driven by functional constraints.
- ❧ Shared pattern of ontogenetic and evolutionary modularity indicates conservatism of modularity. patterns driven by developmental constraints.
- ❧ Allometry greatly influences the overall modularity and integration pattern.
- ❧ The main implication is that cranial modularity is shaped by complex interaction of functional and developmental constraints.

Thank you for your attention!

