**Macroevolution of dimensionless life histories in amniotes**

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**Objectives**

1. Use Charnov’s dimensionless life history traits to visualize and quantify the life history strategies of amniotes
2. Compare life history strategies of birds, mammals, reptiles, and smaller clades by using hypervolumes
3. Investigate if these so-called invariant traits are actually invariant with body mass
4. Analyze the macroevolutionary patterns of the dimensionless traits and their components between clades

**Motivation:** How do evolutionary history and ecological roles interact to influence the trait combinations possible for a group of species?

**Charnov’s Dimensionless Traits**

Most life history traits vary with body mass. 3 dimensionless variables hypothesized to be invariant with body mass (Charnov 2002):

1. \( C \cdot E = \text{reproductive effort} \cdot \text{average lifespan} \)
   - Fraction of body mass allocated to reproduction per unit death
   - Trade-off of reproductive effort and mortality rate

2. \( E/\alpha = \text{average lifespan} / \text{age at female maturity} \)
   - Cost of aging to reproductive maturity relative to lifespan
   - Trade-off of reproductive age and overall lifespan

3. \( I/m = \text{mass at independence} / \text{adult body mass} \)
   - Size of independent offspring relative to adult
   - Trade-off of offspring size compared to adult size
   - These traits thus represent trade-offs that are presumably provide information beyond body mass.

**Data**

Used the Myhrvold et al. 2015 amniote database augmented with reptile data from Allen et al. 2017

849 mammals, 516 reptiles, and 171 birds with trait values for body mass and the invariants

**Life History Hypervolumes**

4-dimensional Gaussian hypervolumes: framework for classifying life histories

![Figure 1. Hypervolumes for birds (n=171), mammals (n=849), and reptiles (n=516). Bird hypervolume volume is 29.25, mammal is 205.82, and reptile is 474.93.](image)

**Reptile Order Hypervolumes**

- Crocodylia
- Squamata
- Testudines

![Figure 2. Reptile hypervolume showing the location of the three orders: Crocodylia (n=22), Testudines (n=54), and Squamata (n=440).](image)

**Are the invariants really invariant?**

There are multiple ways to quantify invariance beyond p-value (Price et al. 2014), including \( R^2 \) and slope.

**Conclusions & Future Directions**

1. Birds, mammals, and reptiles have very different constraints in life history space.
2. Bats share characteristics with both birds and mammals, so flight may present unique constraints.
3. Charnov’s traits are not always invariant with body mass for all groups of species.

**Future Questions:**

- Does ectothermy allow for a wider range of life history traits?
- What constraints do flight provide?
- Does coevolution of life history traits result in invariance?
- What differs in clades that do not exhibit invariance?

**References**


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