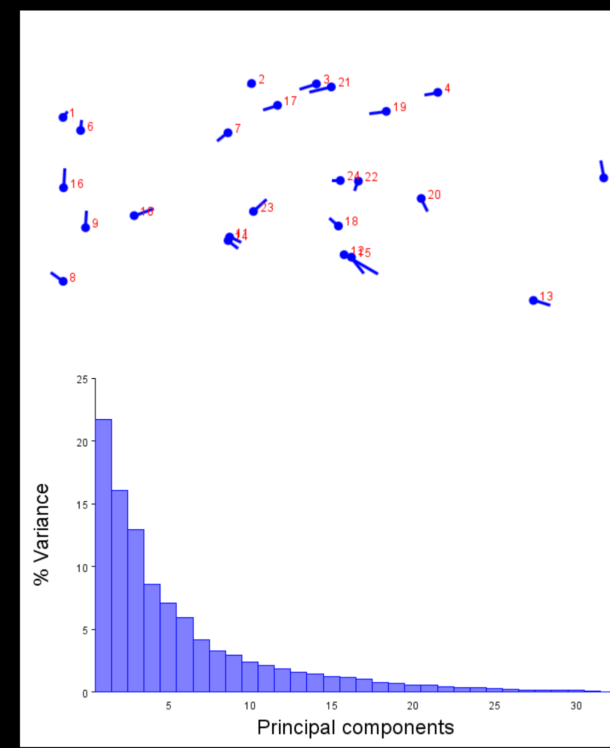
Digital Dinosaurs Lab 05
Geometric Morphometrics

Dr. Phil Morris

Rodents are cooler than dinosaurs, anyway!

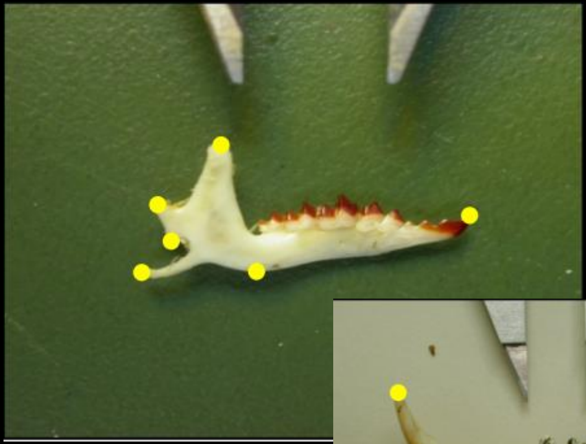


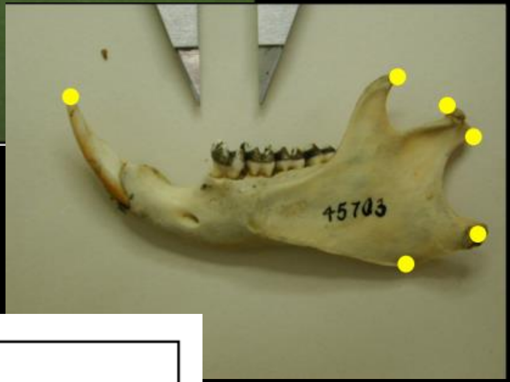
Intro to Geometric Morphometrics

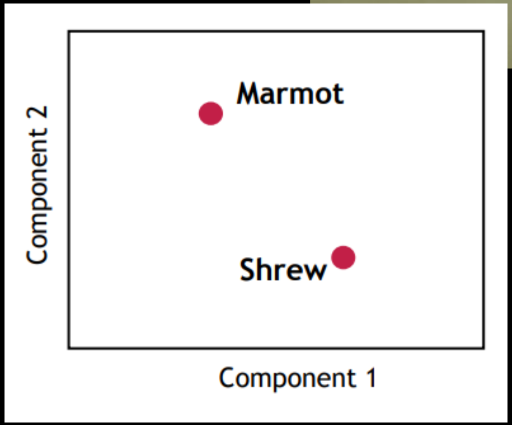
- What is GMM?
- Basic steps in GMM
  - Landmarking
  - Procrustes
  - Shape variation (PCA etc.)
- Uses and strengths of GMM
- How we’re going to use it
  - Practical portion
- Discussion of results

Geometric Morphometrics

- Geometric morphometrics (GMM) is the quantitative representation and quantifiable analysis of form the form of a morphological shape.
- Useful instead of direct linear measurements to characterise more complex collections of shapes.
- The goal of GMM is to measure morphological **similarity** and **difference**

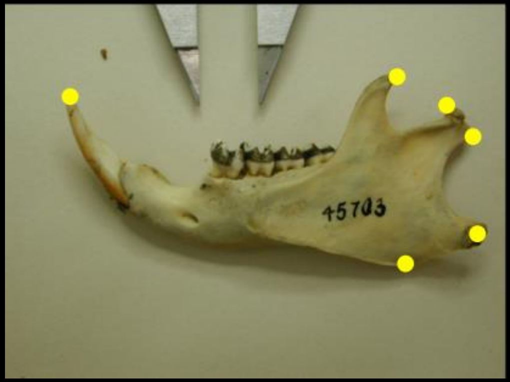


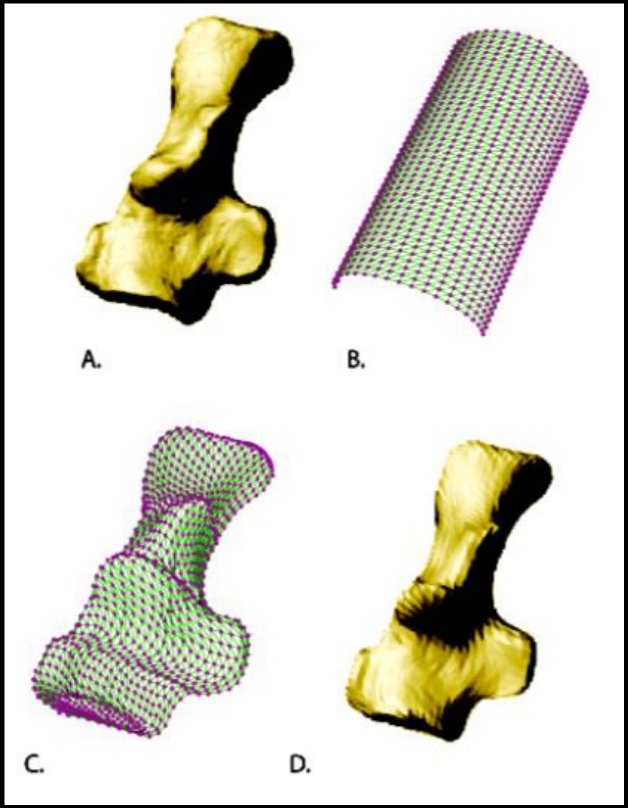




Landmarks

- Landmarks are coordinate points (x, y, z) used to represent a shape through the recording of those coordinates at discrete locations
- Landmarks can be two-dimensional or three-dimensional
- Need to be homologous; you must be able to identify the same location across all specimens





Steps in a Geometric Morphometrics-based Analysis

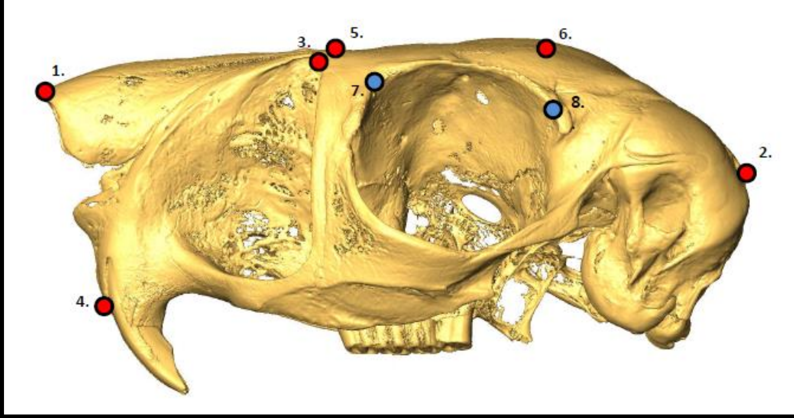
- Collect landmarks

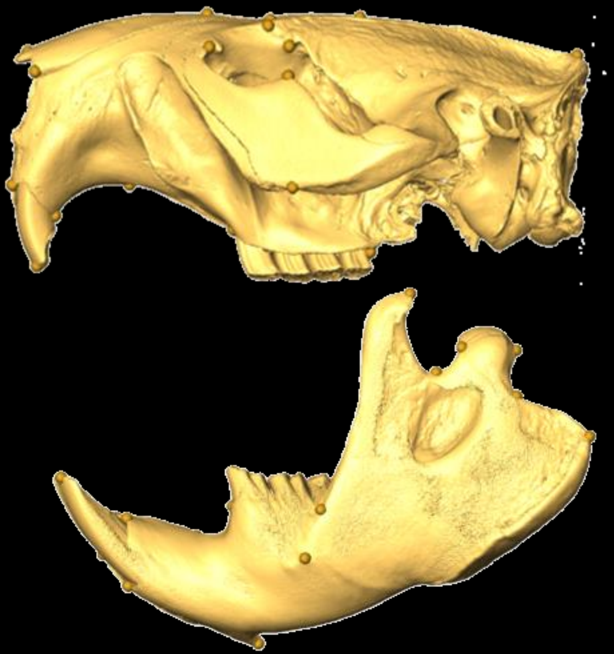
- Perform a Procrustes superimposition
  - Standardizes landmarks by rescaling them and rotating them to a common orientation using least-squares fitting

- Analyse differences and similarities in shape throughout collected sample
  - Analysis usually starts with a Principal Components Analysis, which: (A) shows similarity and differences as scatter plots, and (B) provides new variables for further statistical analysis

Step 1: Landmarking

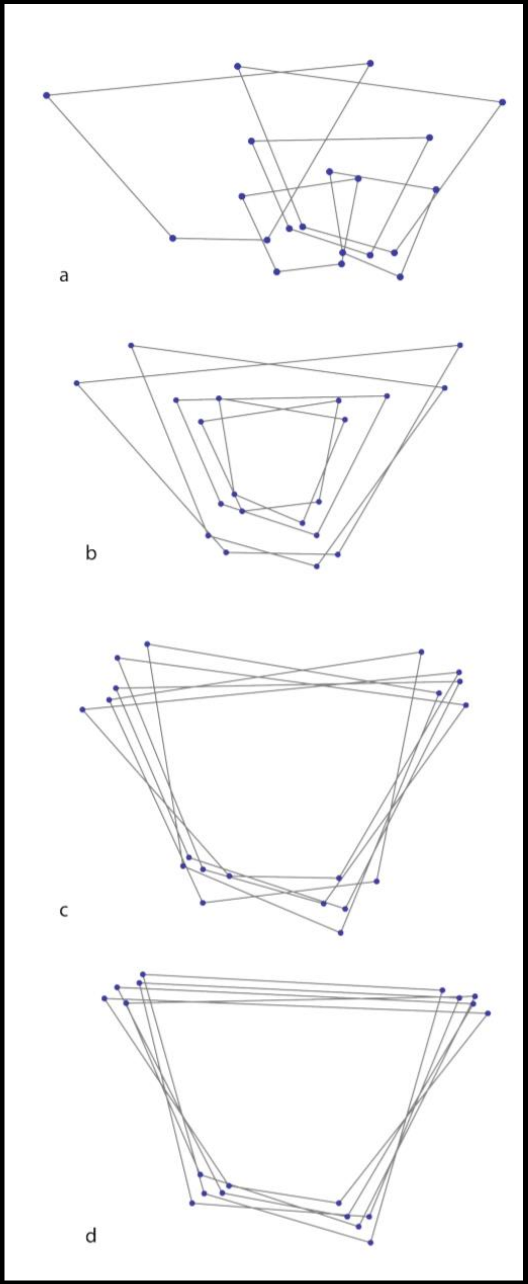
- 1. Each shape must have the same number of landmarks
- 2. The landmarks on all shapes must be in the same order
- 3. Landmarks are ordinarily placed on homologous points, points that can be replicated from object to object based on common morphology, common function, or common geometry





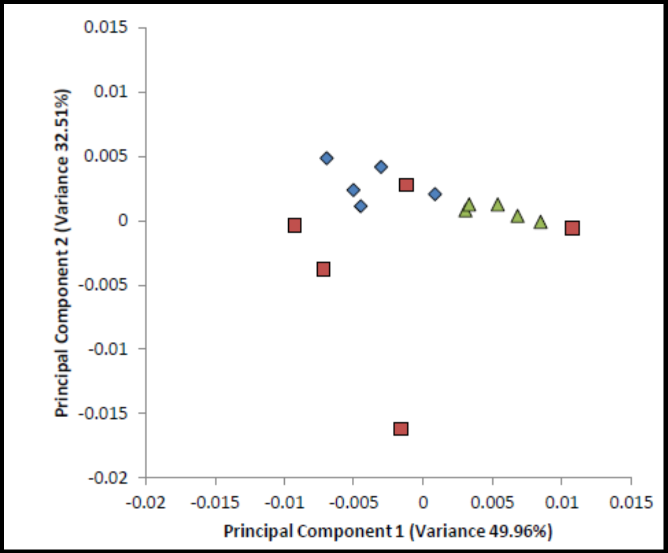
Step 2: Procrustes superimposition

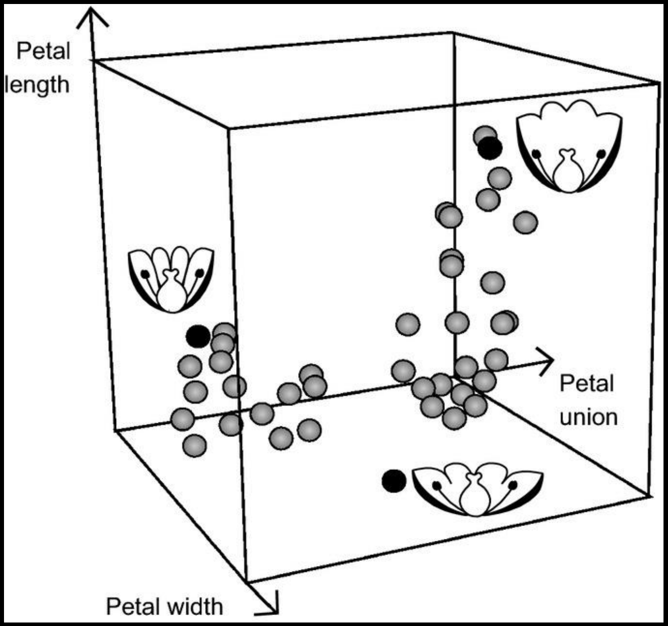
- Procrustes superimposition is the “standardization” step in GMM.
- Procrustes removes
    - 1. size
    - 2. translation
    - 3. rotation
- After landmarks have been superimposed, the similarities and differences in their shape can be analysed.



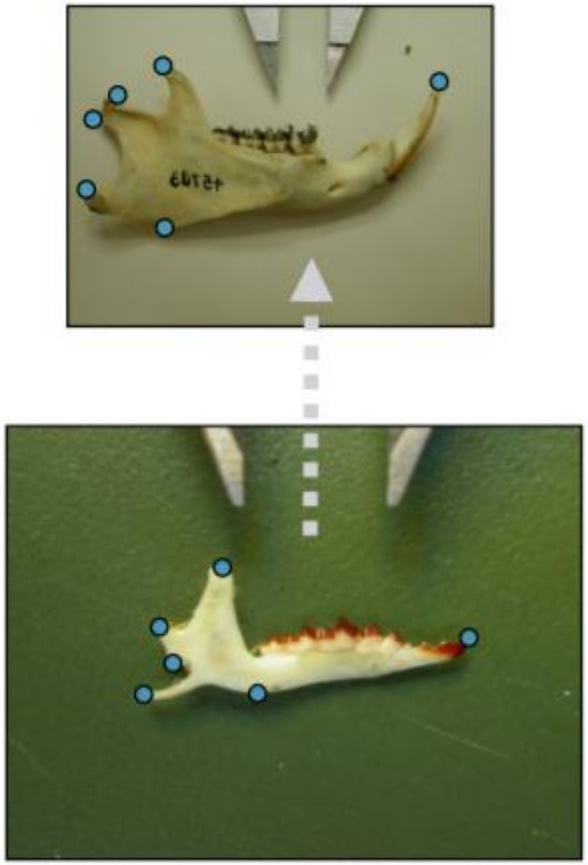
Step 3: Principal Components Analysis

- Principal Components Analysis (PCA) arranges objects in a shape/morpho space. Similarities and differences can easily be seen in a PCA plot.
- The axes of a PCA plot are Principal Components (PCs).
- Each point on a PCA plot represents the shape of **a single object** from your analysis.
- The closer two objects are, the more similar they are in shape.

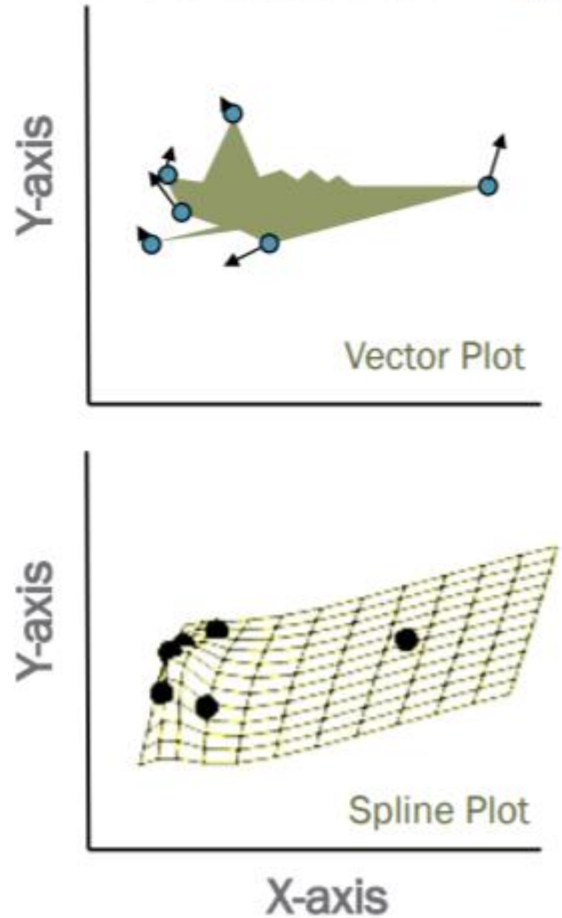




Difference in shape of mandibles of shrew and marmot



Two examples of how the differences are shown graphically



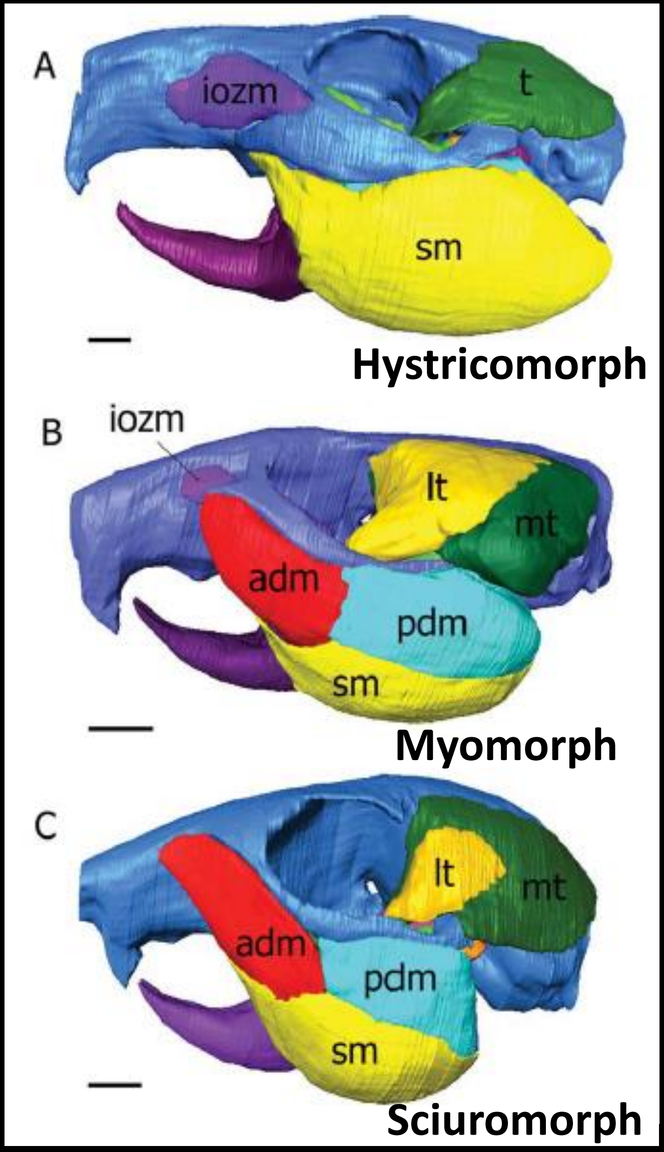
How do we do it?

- Digitizing landmarks and outlines: tpsDIG, ImageJ
- Superimposition: Morpheus (plus integrated in some below)
- Outline analysis: Eigenshape, PAST
- MANOVA: Statistica, PAST
- Discriminant functions, CVA: Statistica, PAST
- Principal components analysis of landmarks: tpsRELW, PST
- Construction of trees: PHYLIP, PAUP, NTSYSpc, PAST
- All of the above plus simulations: Mathematica, R, **MorphoJ**

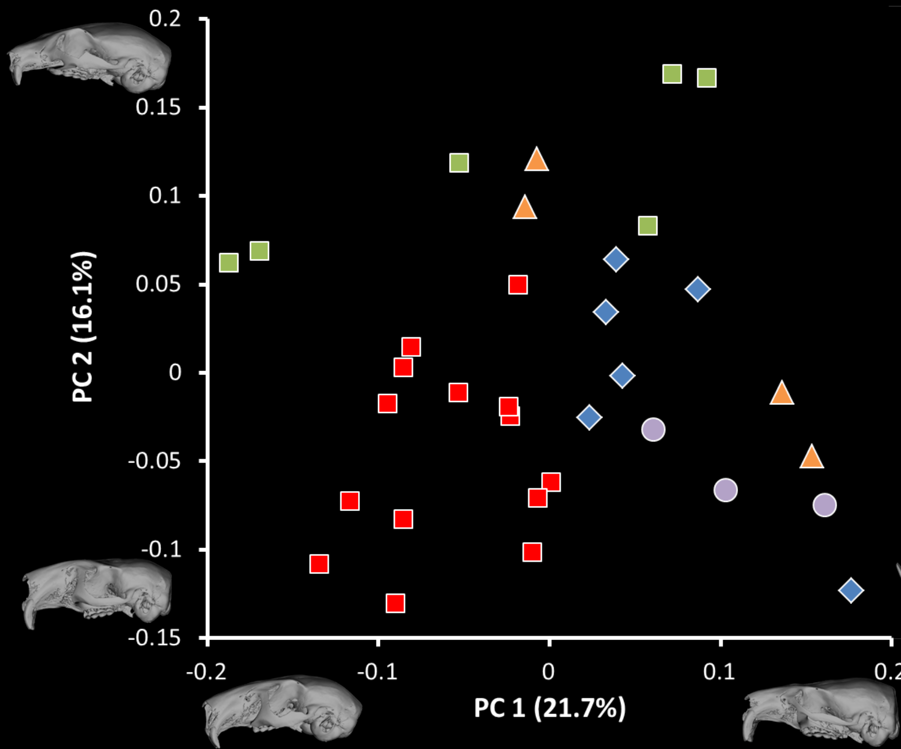
How are we using GMM today?

- All data must:
  - reflect the shape adequately
  - Have all landmarks be present on all specimens
  - **Reflect a hypothesis…**

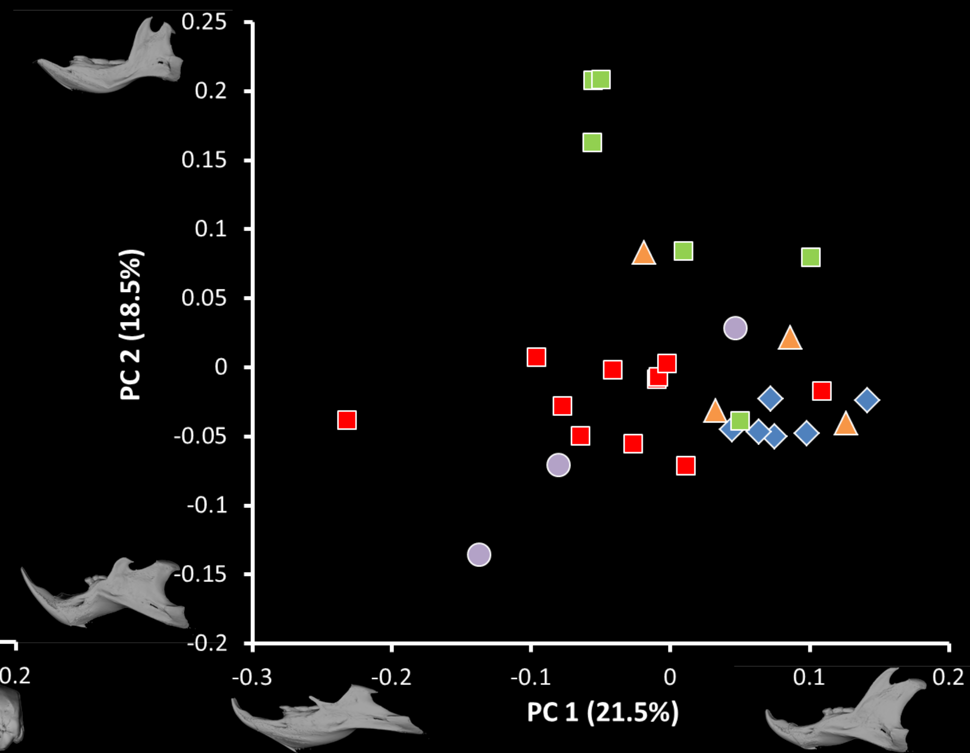
- **“Are discrete groups formed as a result of the presence of different forms of masticatory musculature in rodents?”**



PCA Results



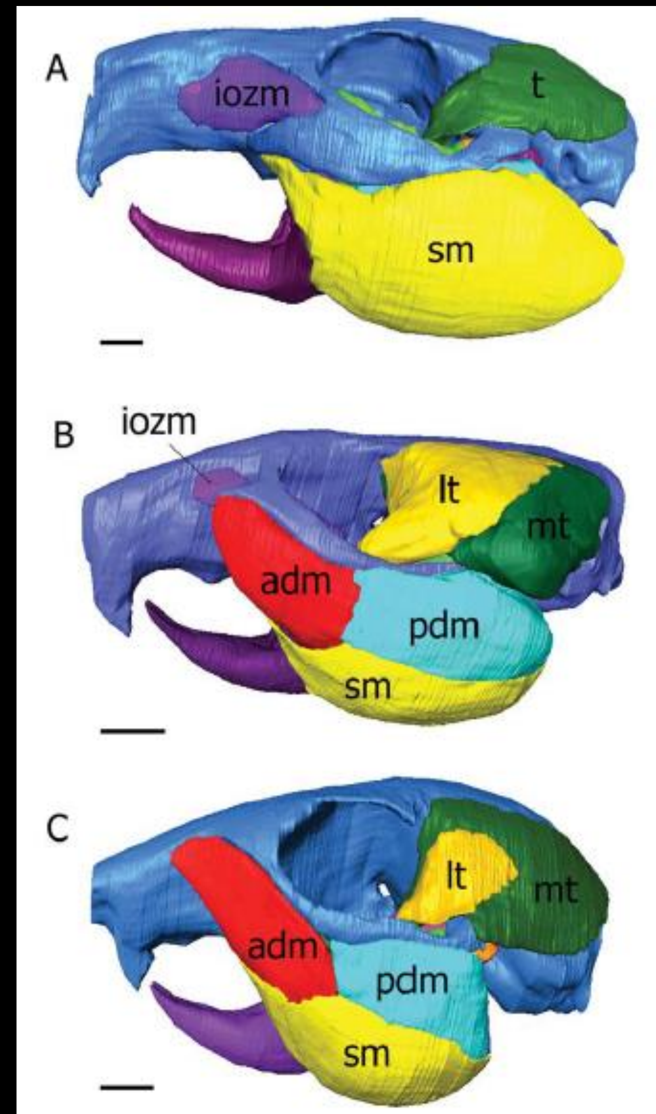
Cranial PCA Results



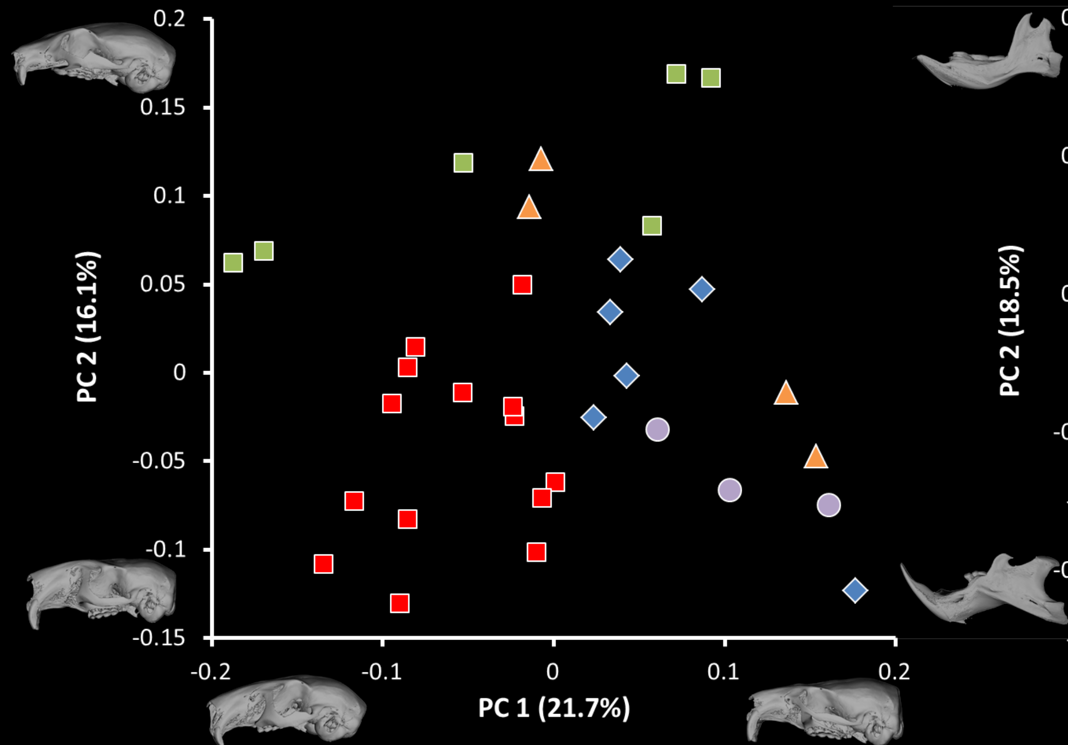
Mandibular PCA Results

- ■ = Non-rodent
- ■ = Hystricomorph
- ◆ = Myomorph
- ▲ = Sciuromorph
- ● = Protrogomorph

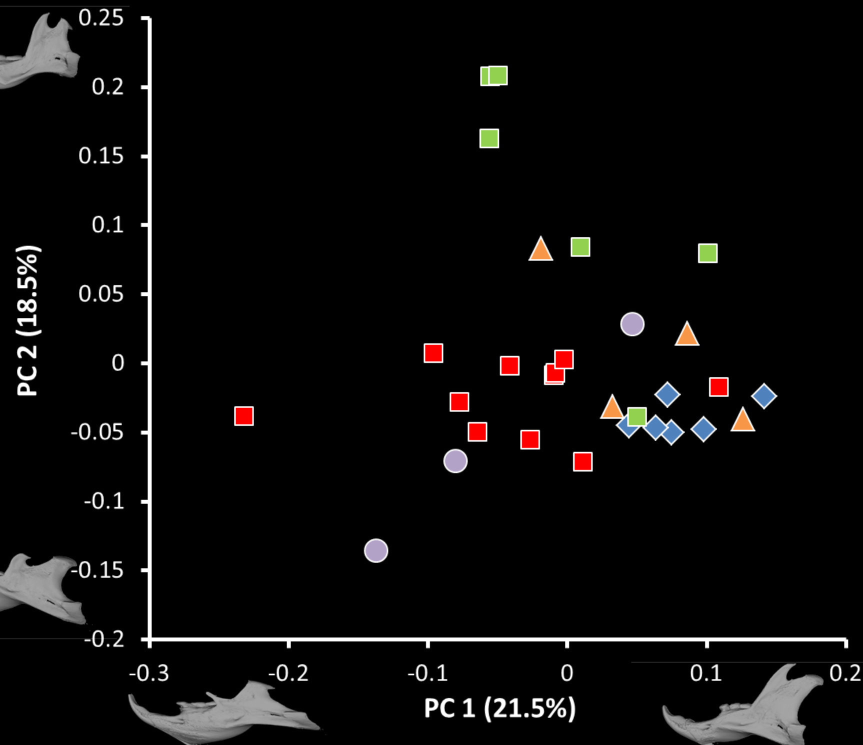
Results



PCA Results



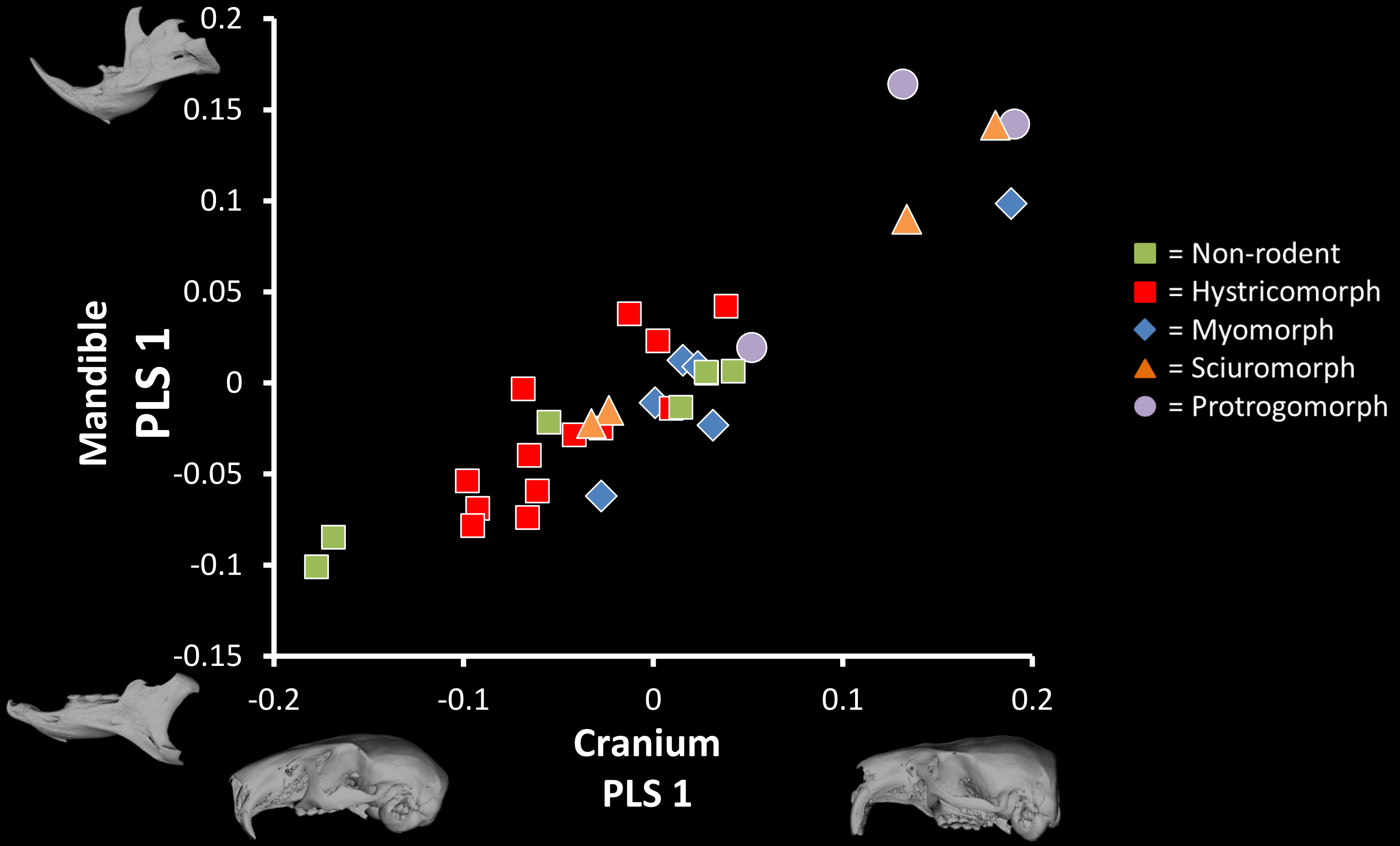
Cranial PCA Results



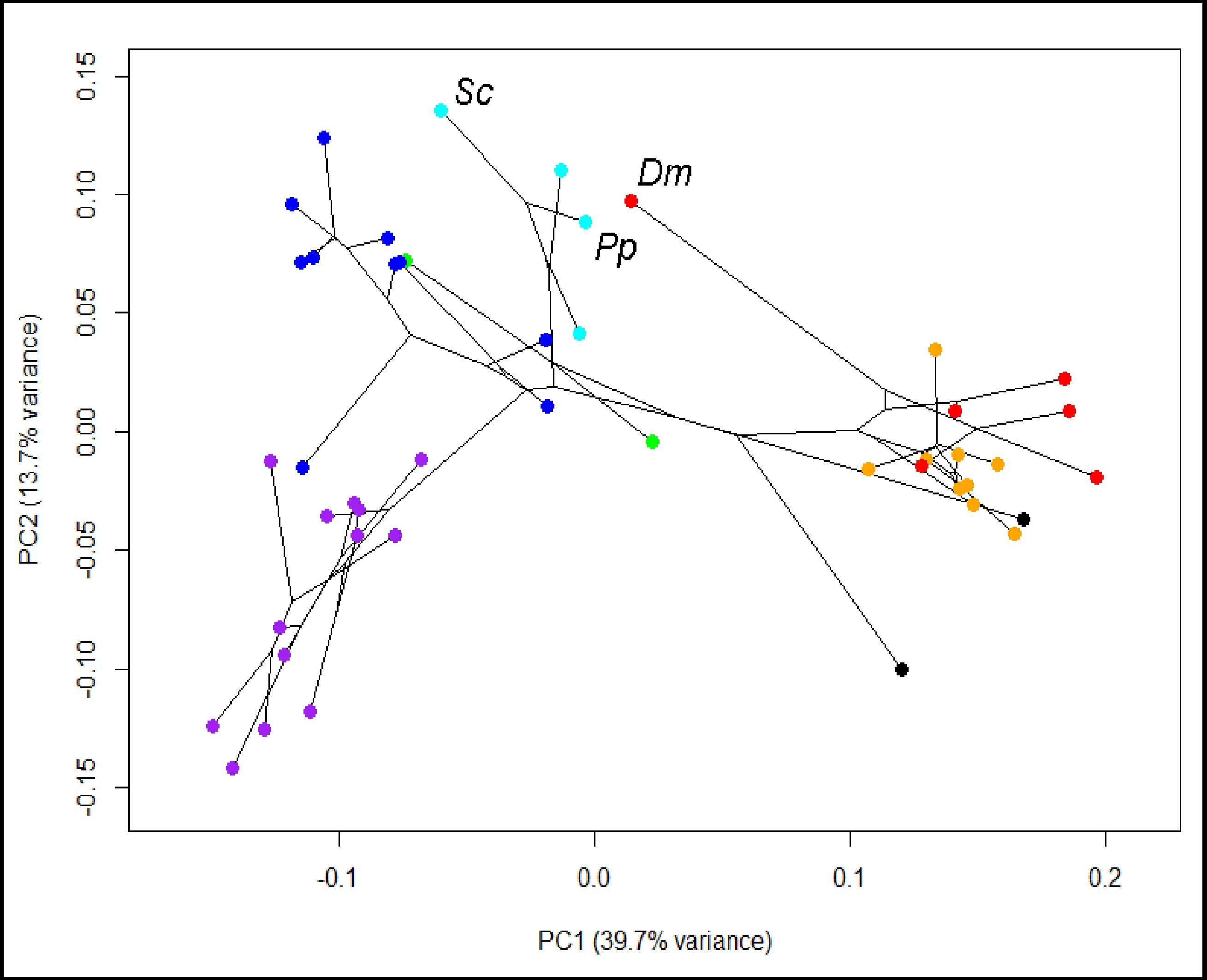
Mandibular PCA Results

= Non-rodent
= Hystricomorph
= Myomorph
= Sciuromorph
= Protrogomorph

Covariation



- The results of this study show that both the cranium and the mandible of the aye-aye are morphologically convergent with those of sciurid rodents.



ROYAL SOCIETY
OPEN SCIENCE

royalsocietypublishing.org/journal/rsos

Research

Cite this article: Morris PJR, Cox PG, Cobb SN. 2019 Mechanical significance of morphological variation in diprotodont incisors. *R. Soc. open sci.* **6**: 181317.
http://dx.doi.org/10.1098/rsos.181317

Received: 12 August 2018
Accepted: 20 February 2019

Subject Category:
Biology (whole organism)

Mechanical significance of morphological variation in diprotodont incisors

Philip J. R. Morris[1], Philip G. Cox[2] and Samuel N. Cobb[2]

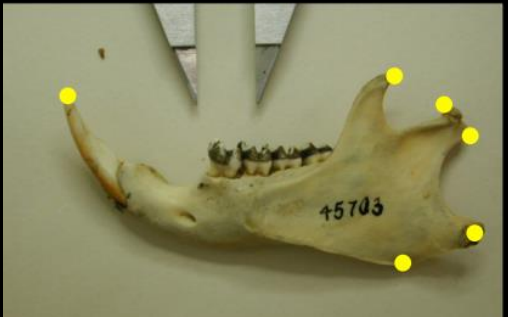
[1]Hull York Medical School, University of Hull, Hull HU6 7RX, UK
[2]Department of Archaeology and Hull York Medical School, University of York, York YO10 5DD, UK

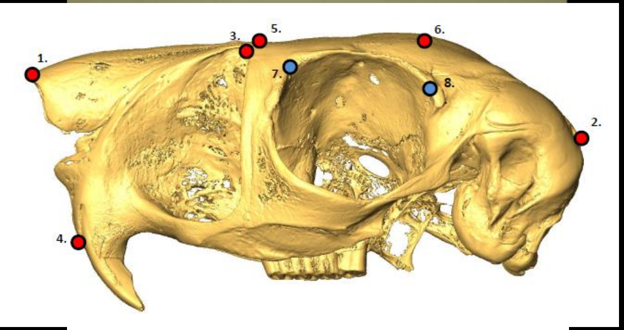
PGC, 0000-0001-9782-2358; SNC, 0000-0002-8360-8024

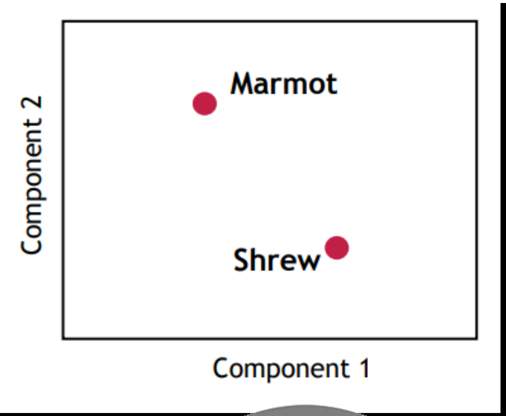
All rodents possess a single pair of enlarged incisors that grow throughout life. This condition (diprotodonty) is characteristic of Rodentia, but is also found in other mammals such as lagomorphs, hyraxes, the aye-aye and common wombat. This study surveyed lower incisor morphology across extant diprotodonts to examine shape variation within and between rodents and other diprotodonts, and to determine if tooth shape varies in a manner predictable from mechanics. Six linear and area variables were recorded from microCT scans of the mandibles of 33 diprotodont mammals. The curvature of the rodent lower incisors, as measured by the proportion of a circle it occupies, was shown to vary between 20 and 45%, with non-Glires taxa falling outside this range. Relative

Summary

- Geometric morphometrics (GMM) is the quantitative representation and quantifiable analysis of form the form of a morphological shape.
- Useful instead of direct linear measurements to characterise more complex collections of shapes.
- The goal of GMM is to measure morphological **similarity** and **difference**
- Results can be presented visually as a “shape” than tables of numbers
- Data are easily collected from digital photographs or virtual models
- Size is mathematically removed from the analysis to focus on pure shape







DIGITAL DINOSAURS