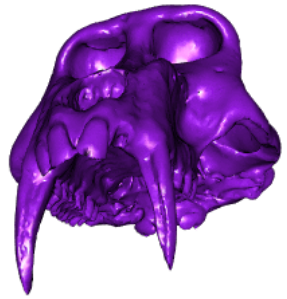
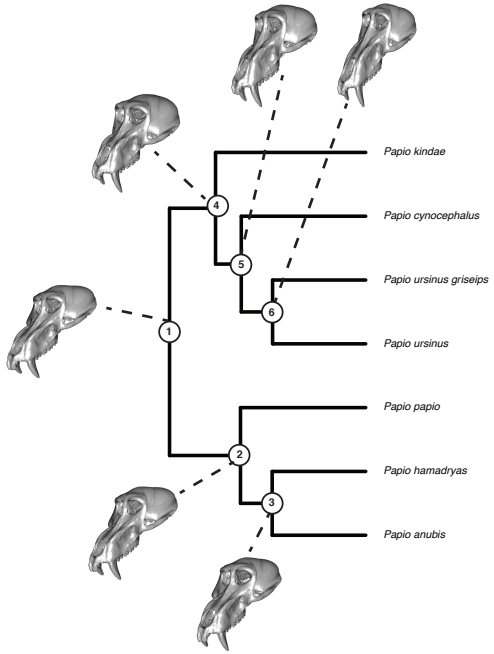
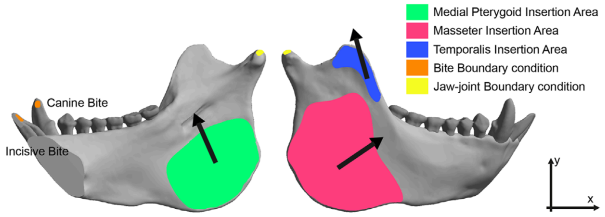
VIRTUAL ECOMORPHOLOGY

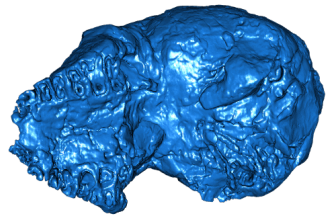
Combining GM + Biomechanics + PCMs

Dr. Thomas A. Püschel









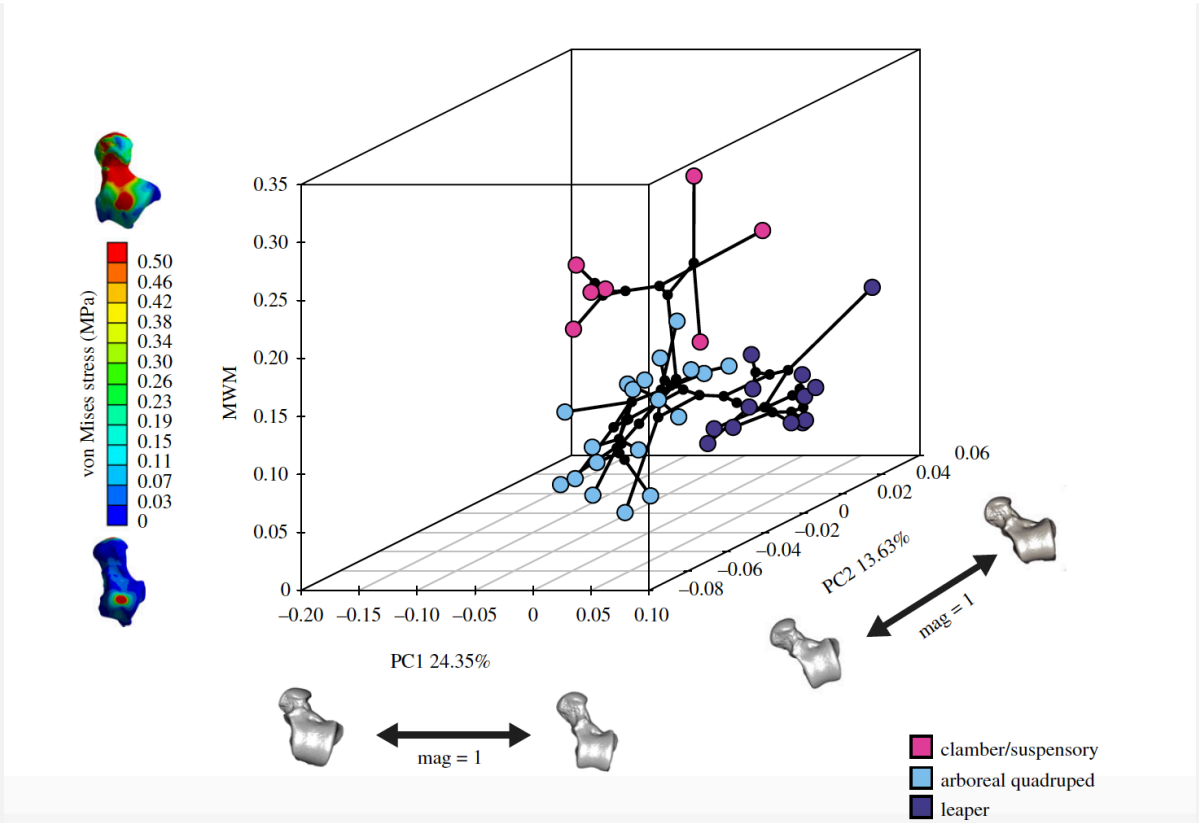
Primate Models for Behavioural Evolution LAB

LEVERHULME TRUST

UNIVERSITY OF OXFORD

Outline

- Introduction
- Biomechanics (FEA)
- GM
- PCMs
- Possible workflow
- Examples
- Conclusion



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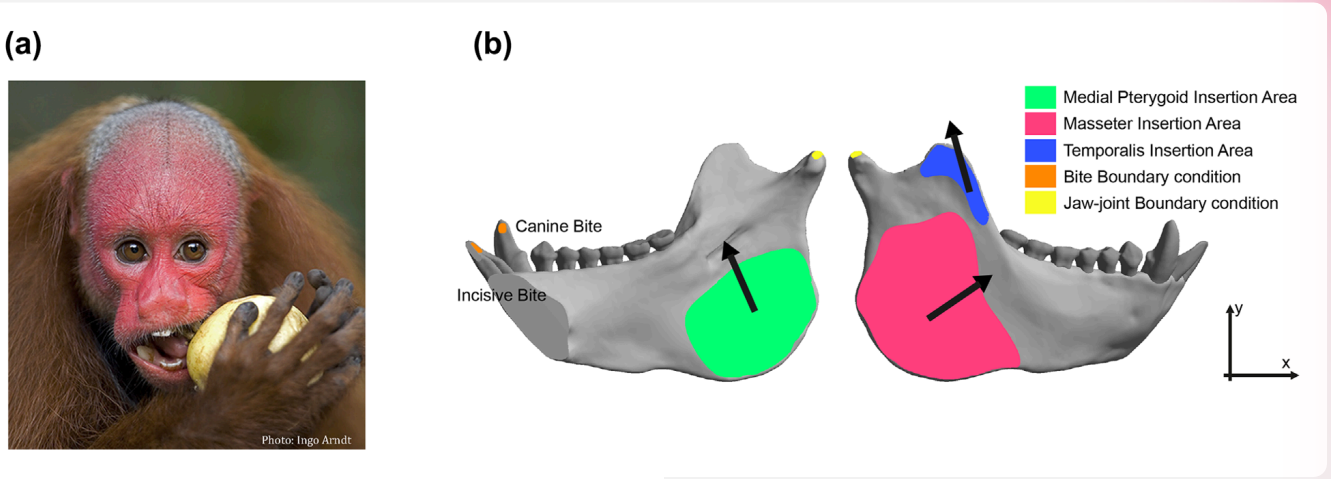
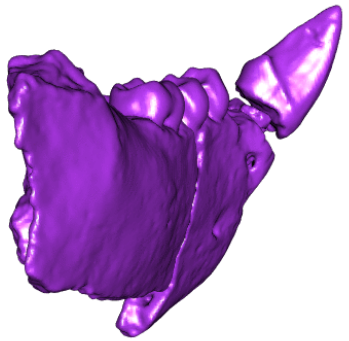
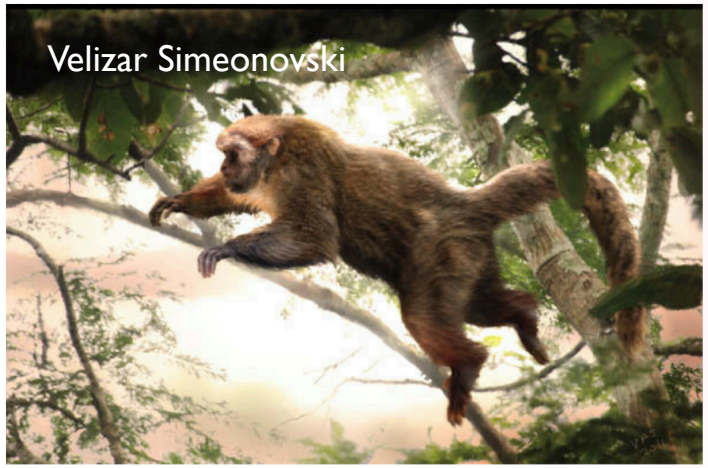
Ecomorphology

- Ecomorphology or ecological morphology can be defined as **the characterisation of the adaptive relationship between the morphology of an organism and its ecological role.**







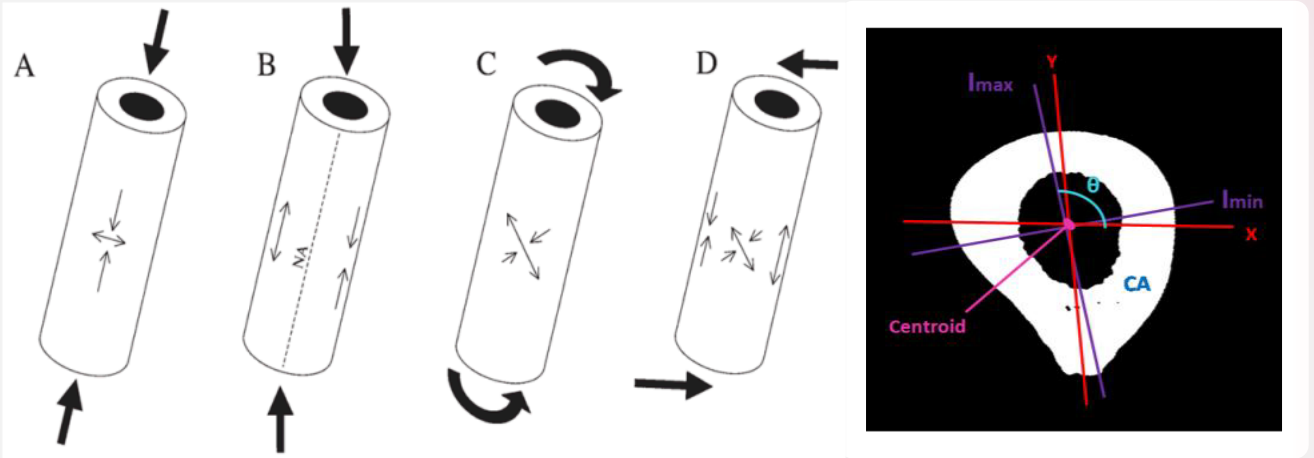
Cebupithecia sarmientoi

Püschel, T. A., Marcé-Nogué, J., Kaiser, T. M., Brocklehurst, R. J., and Sellers, W. I. (2018). Analyzing the sclerocarpy adaptations of the Pitheciidae mandible. *American Journal of Primatology* 80, e22759. doi:10.1002/ajp.22759.

Function: Biomechanics

- Biomechanics is the discipline that applies mechanical principles to biological systems

- The application of biomechanical principles to vertebrate skeletons has a long history that can be traced back to Galileo (1638) and Borelli (1680) .



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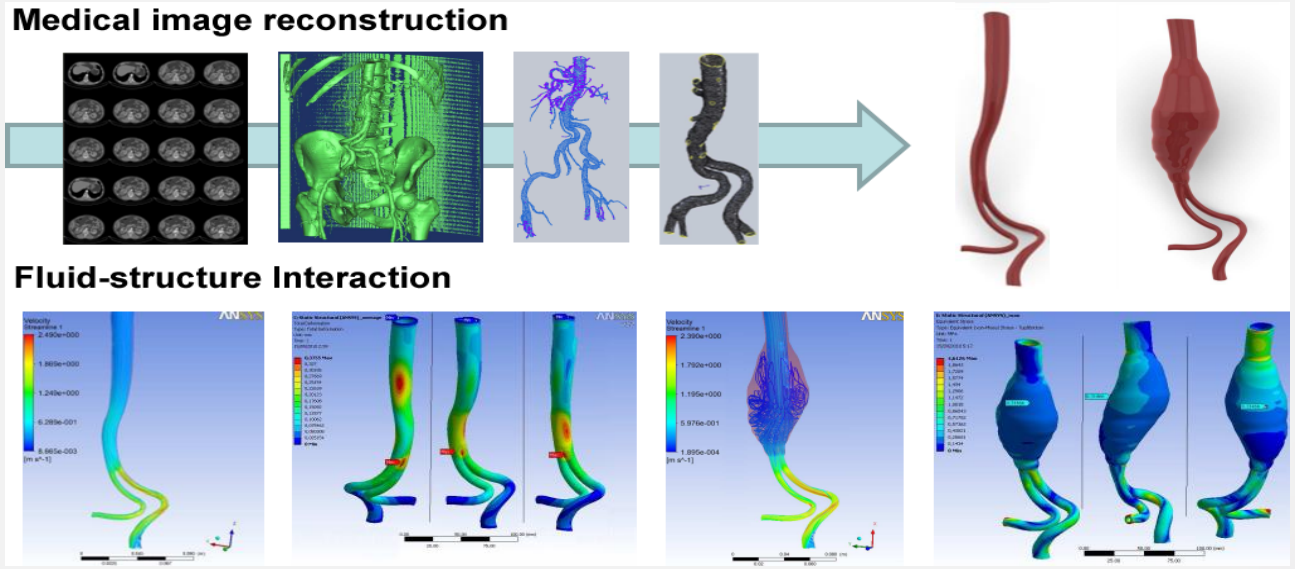
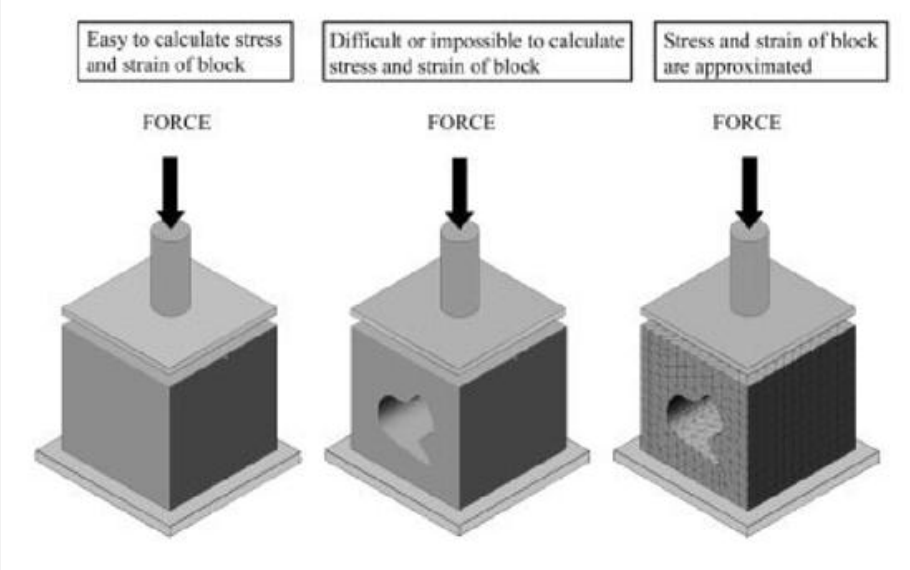


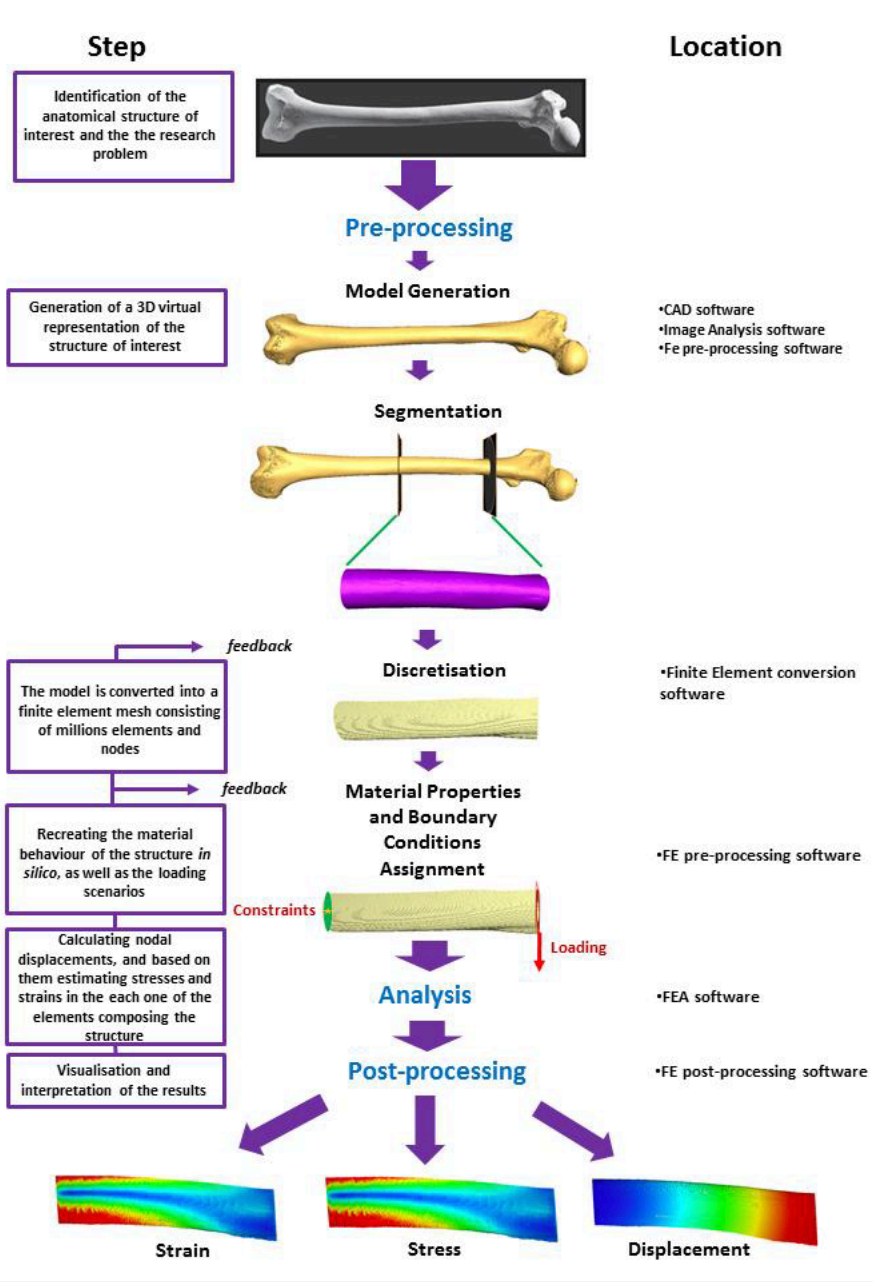
Jordi Marcé-Nogué https://featunning.weebly.com/hemodynamics.html

Finite Element Analysis

Finite Element Analysis (FEA) is a general modelling technique that can be used for structural, thermal, fluid, and acoustic analyses, amongst others.



Richmond, B. G., Wright, B. W., Grosse, I., Dechow, P. C., Ross, C. F., Spencer, M. A., et al. (2005). Finite element analysis in functional morphology. *The Anatomical Record Part A: Discoveries in Molecular, Cellular, and Evolutionary Biology* 283A, 259–274. doi:10.1002/ar.a.20169.



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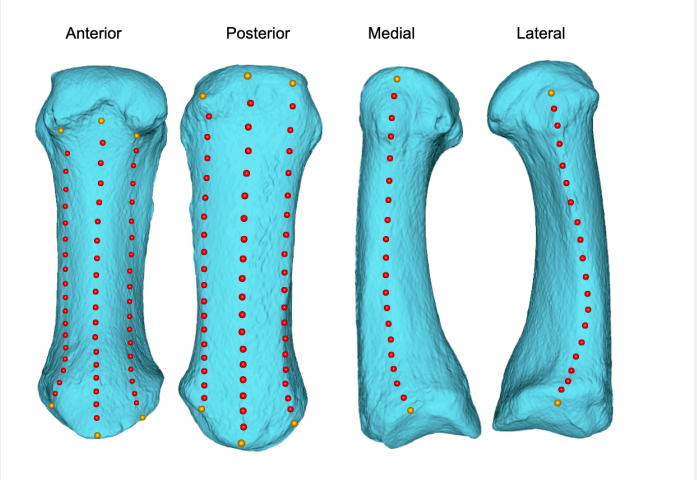
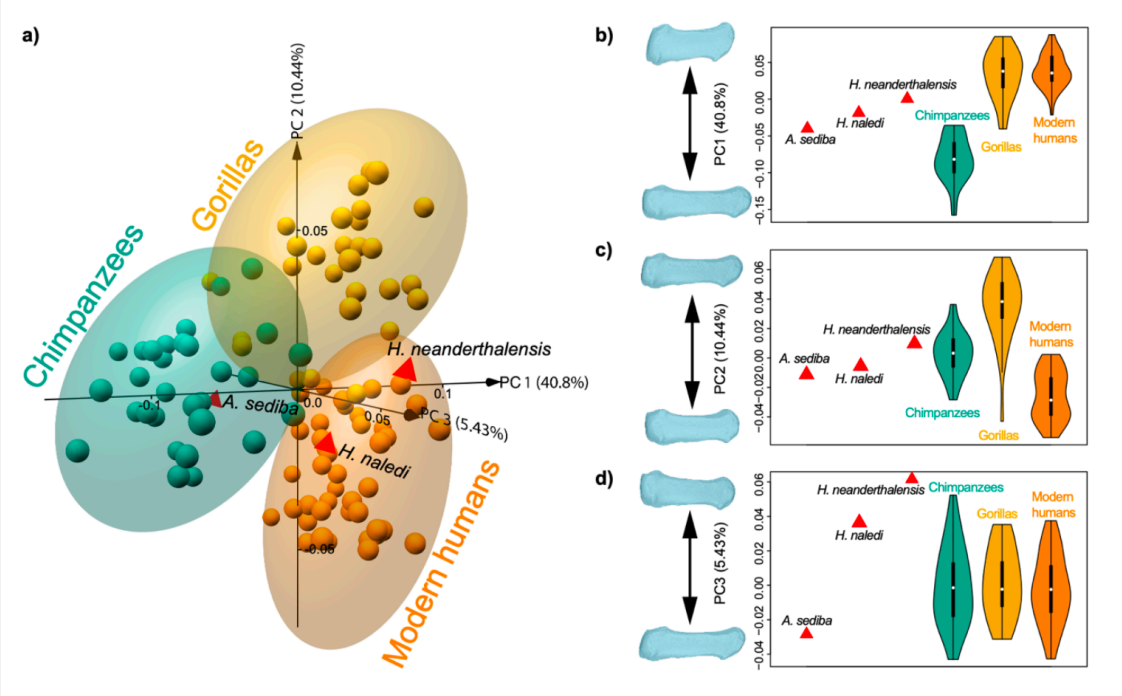
Shape

- **Geometric morphometrics (GM)** comprise a set of techniques for the analysis of form (i.e. shape and size) that utilise as primary data Cartesian coordinates rather than linear distances, angles, ratios or other measurements.

- GM has become the standard tool to quantify morphology in organismal biology.



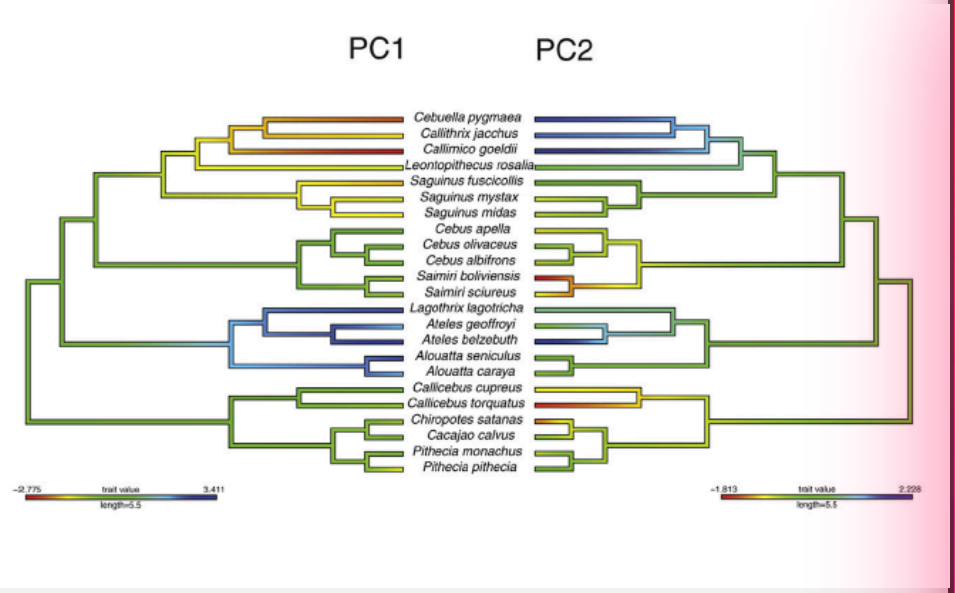


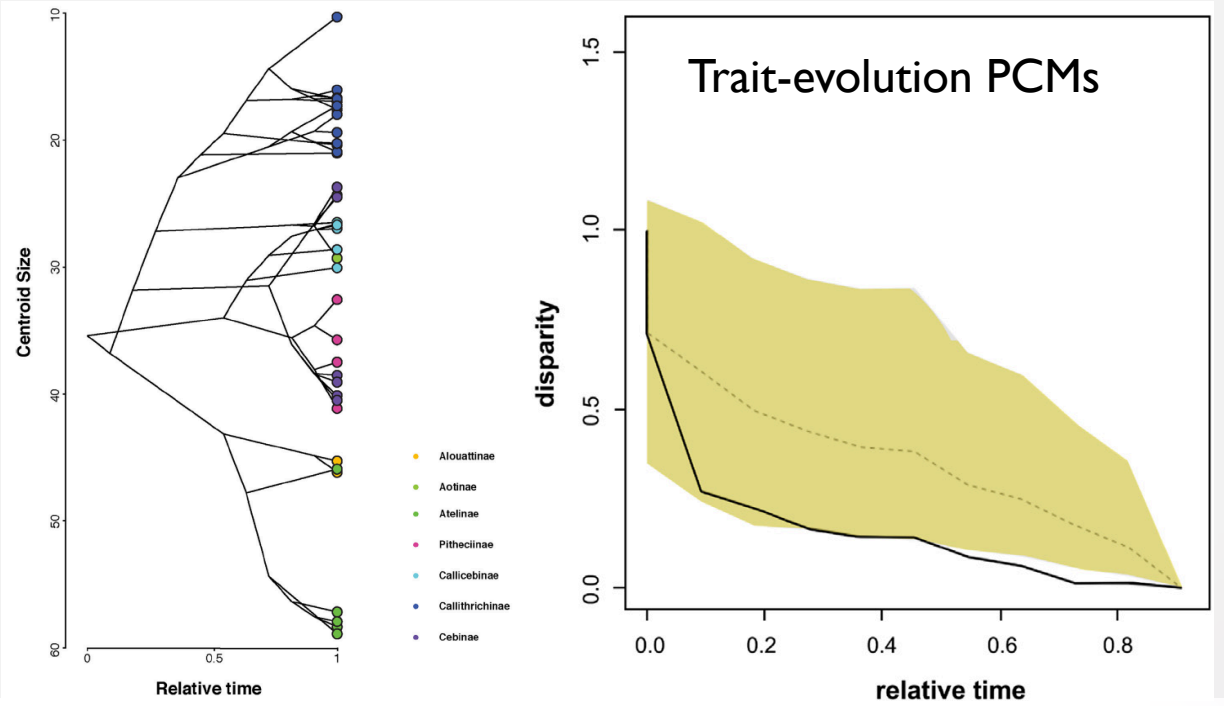
Morley, J., Bucchi, A., Lorenzo, C., and Püschel, T. A. (2020). Characterizing the body morphology of the first metacarpal in the Hominidae using 3D geometric morphometrics. *bioRxiv*, 2020.04.30.070326. doi:10.1101/2020.04.30.070326.

Phylogenetic comparative methods (PCMs)

- Modern **phylogenetic comparative methods** (PCMs) area series of statistical procedures applied to analyse phylogenetic trees, and frequently, their association with trait/phenotypic data.

- Currently there are two main sub-families of methods within the PCMs, which can be broadly classified as those focused on **trait evolution** and those used to investigate **lineage diversification**.





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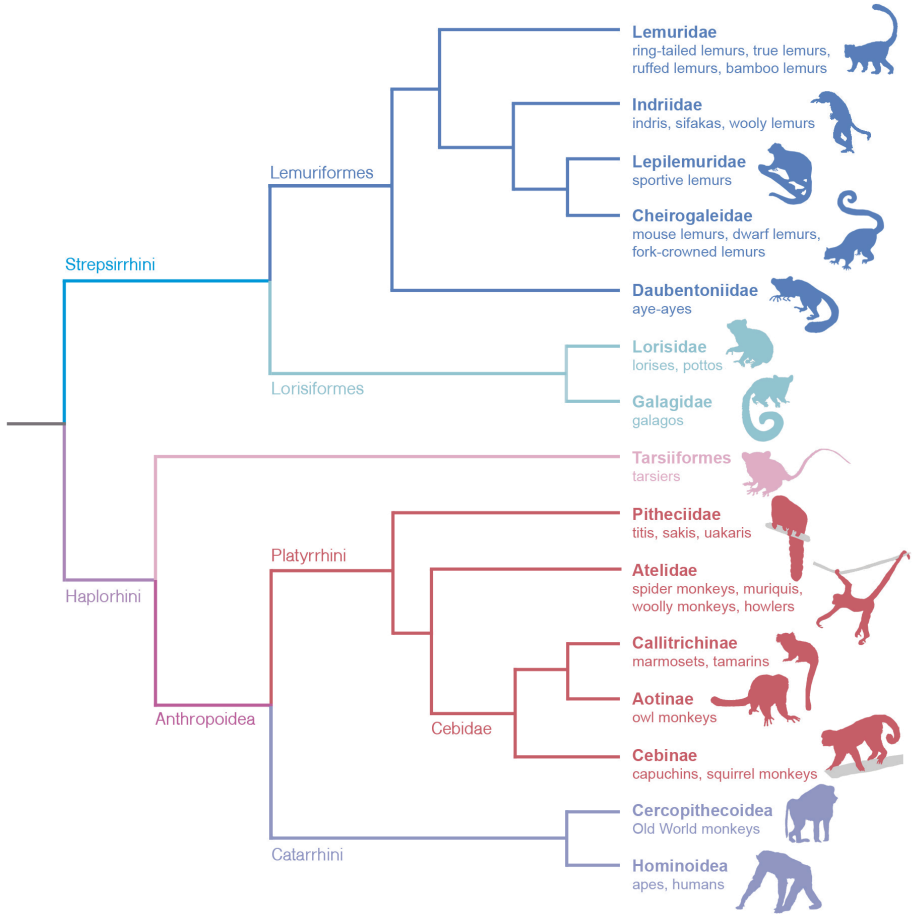
Primates

- Extant primates are quite diverse, with more than ~ 600 species recognised by the IUCN https://www.iucn.org/ ranging in size from minuscule mouse lemurs (30 g) to large gorilla silverbacks (200,000 g).

- Most examples in this presentation are focused on platyrrhines or New World Monkeys (NWM).



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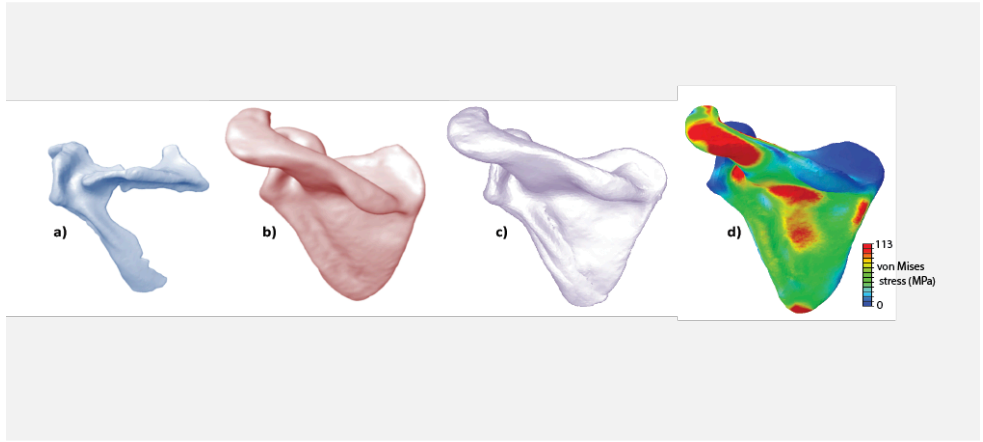
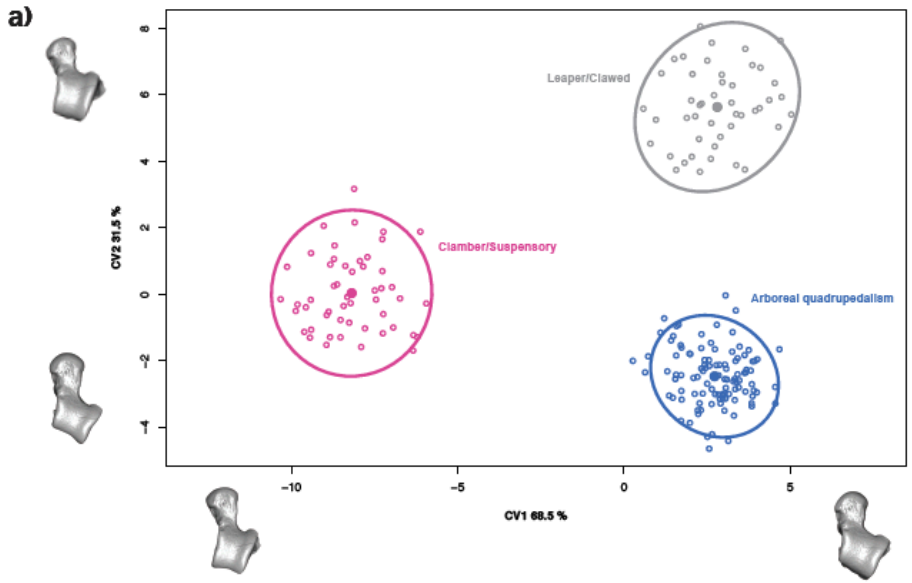
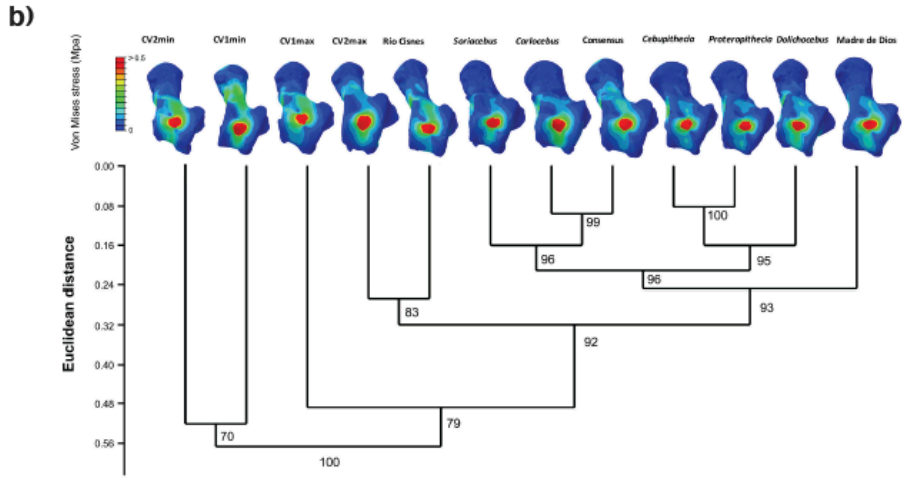
Approaches combining FEA and GM

1. GM as data generation/manipulation tool for FEA







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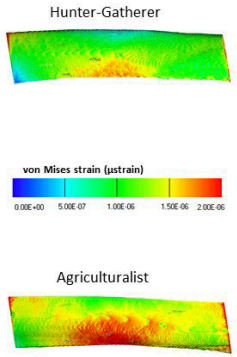
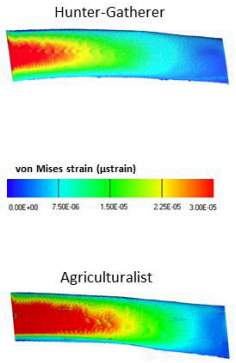
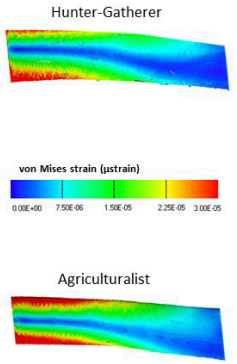
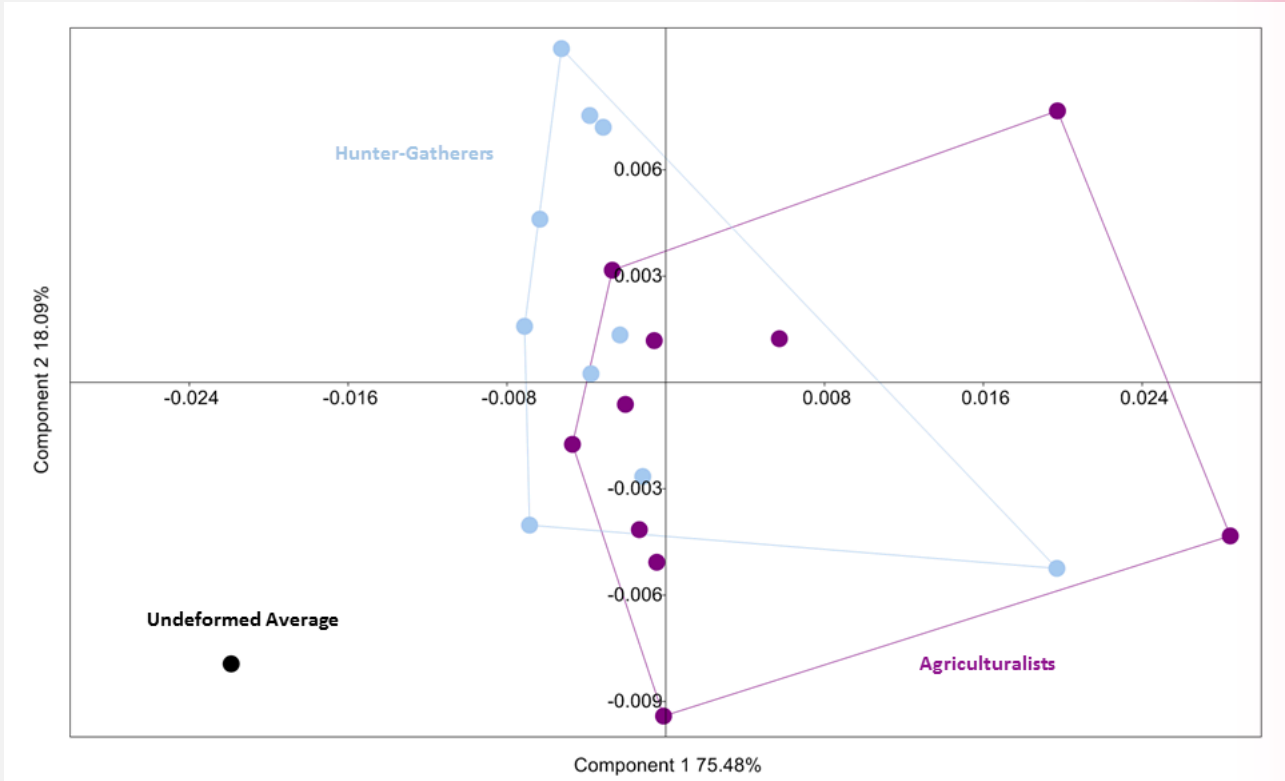
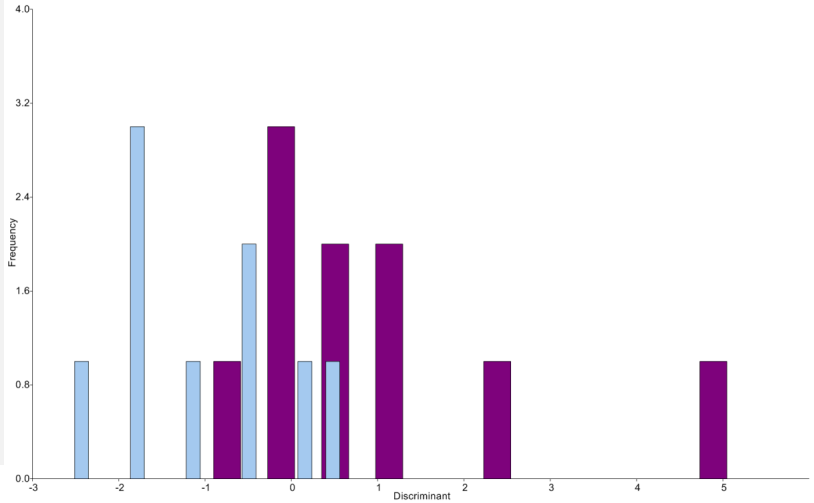
Approaches combining FEA and GM

2. GM as a tool to analyse deformations after FEA analysis

Compression	Medial Bending	Posterior Bending
Hunter-Gatherer 	Hunter-Gatherer 	Hunter-Gatherer 





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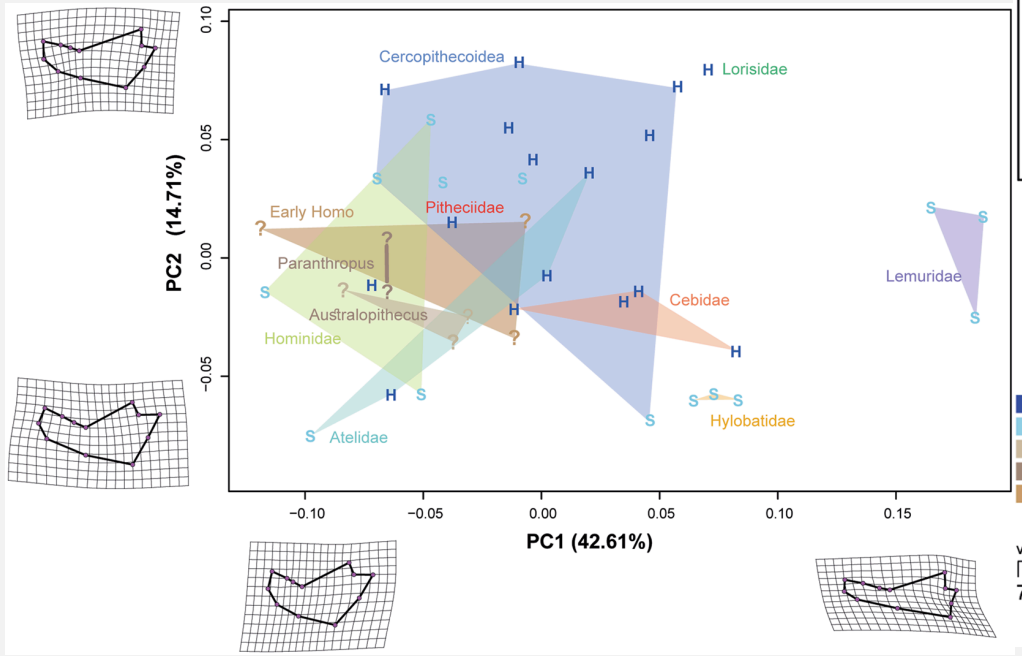
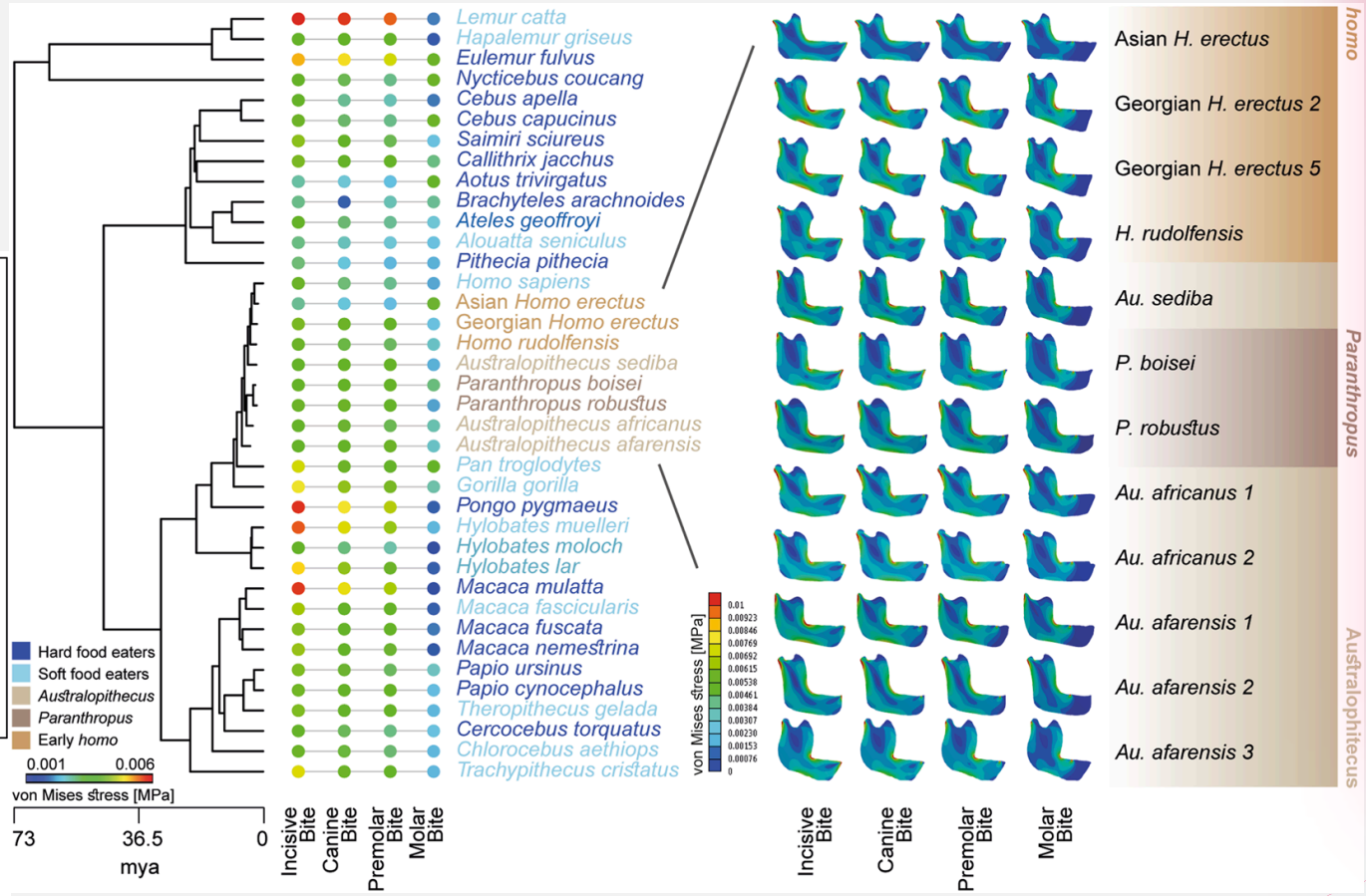
Approaches combining FEA and GM

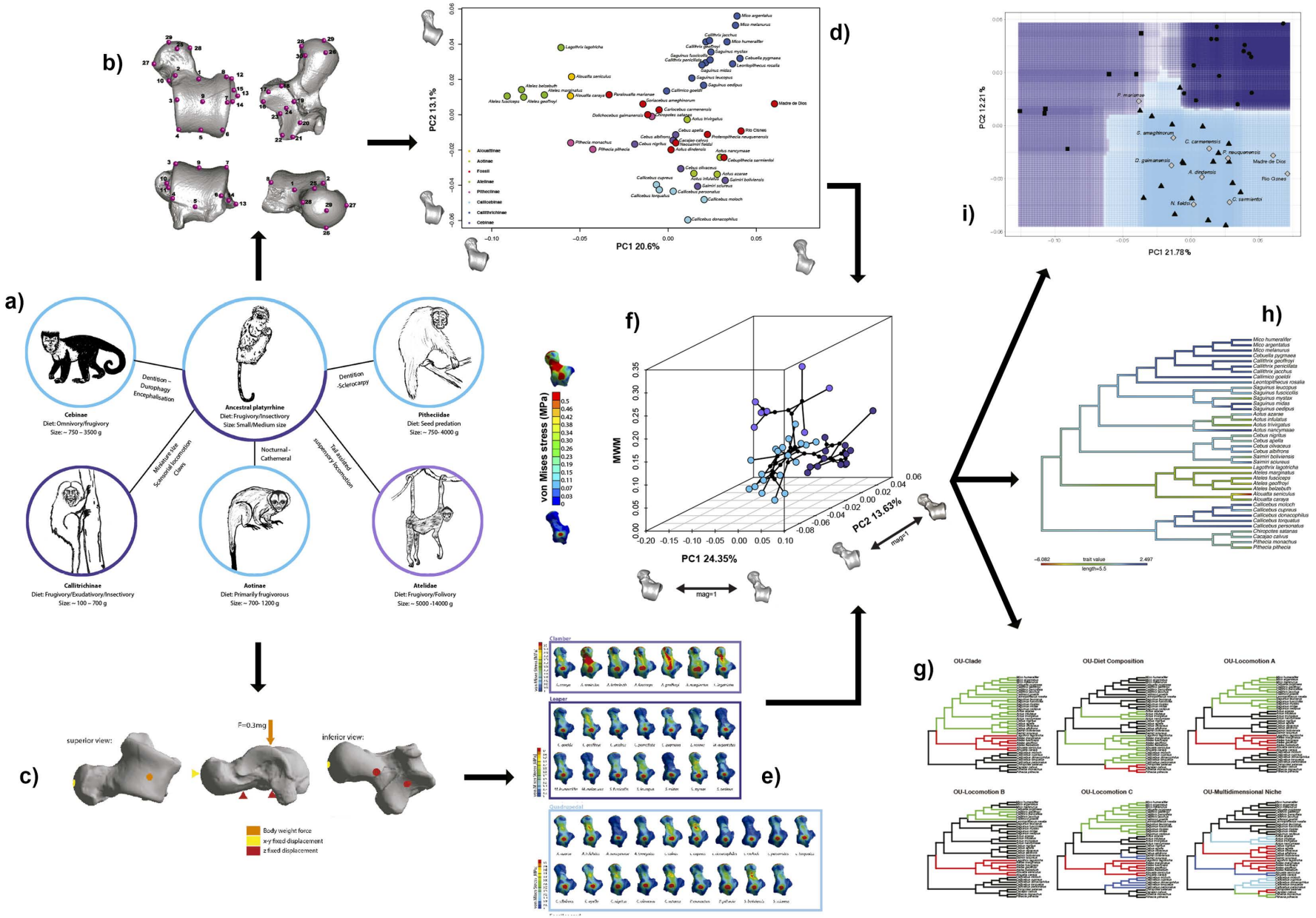
3. GM and FEA combined by analysing their results using multivariate statistical tools





Marcé-Nogué, J., Püschel, T. A., Daasch, A., and Kaiser, T. M. (2020). Broad-scale morpho-functional traits of the mandible suggest no hard food adaptation in the hominin lineage. *Sci Rep* 10, 1–11. doi:10.1038/s41598-020-63739-5.

A possible workflow



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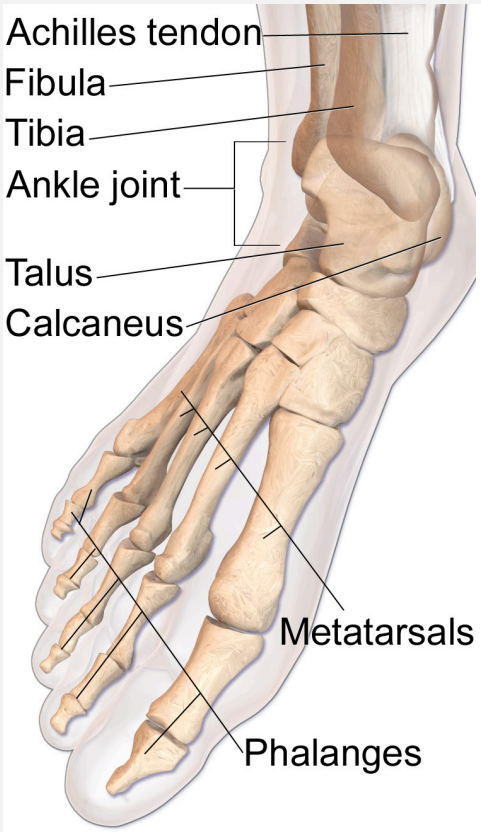
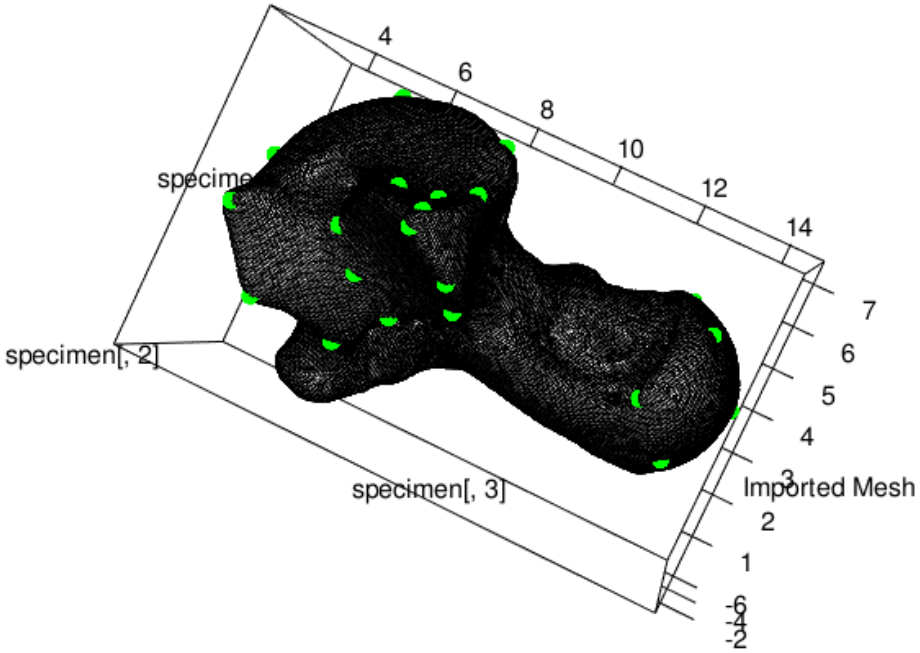
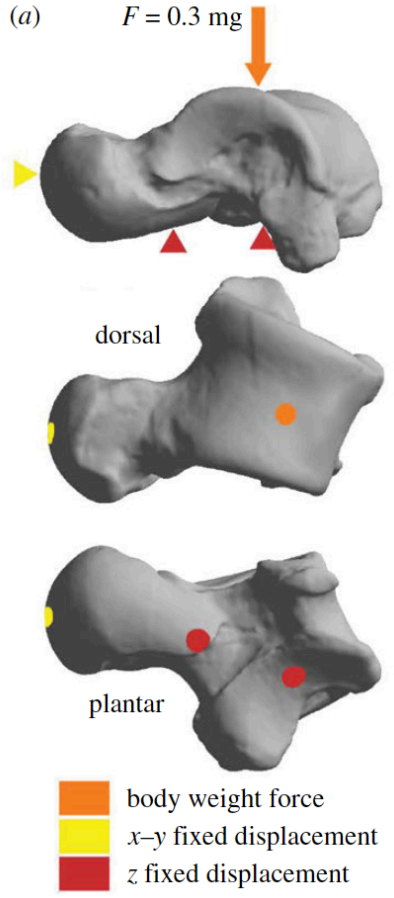
Example: the platyrrhine talus



Lower Leg and Foot





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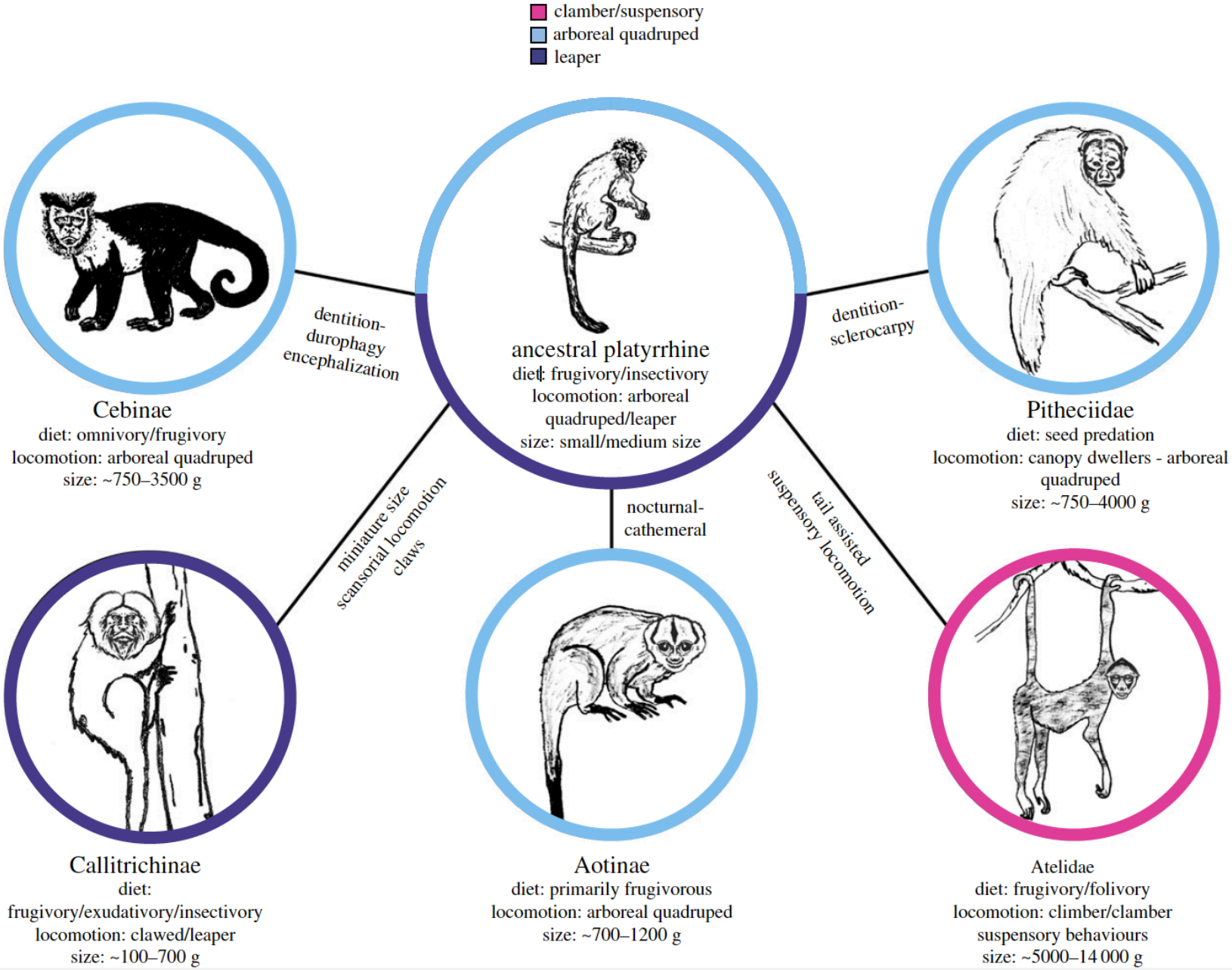

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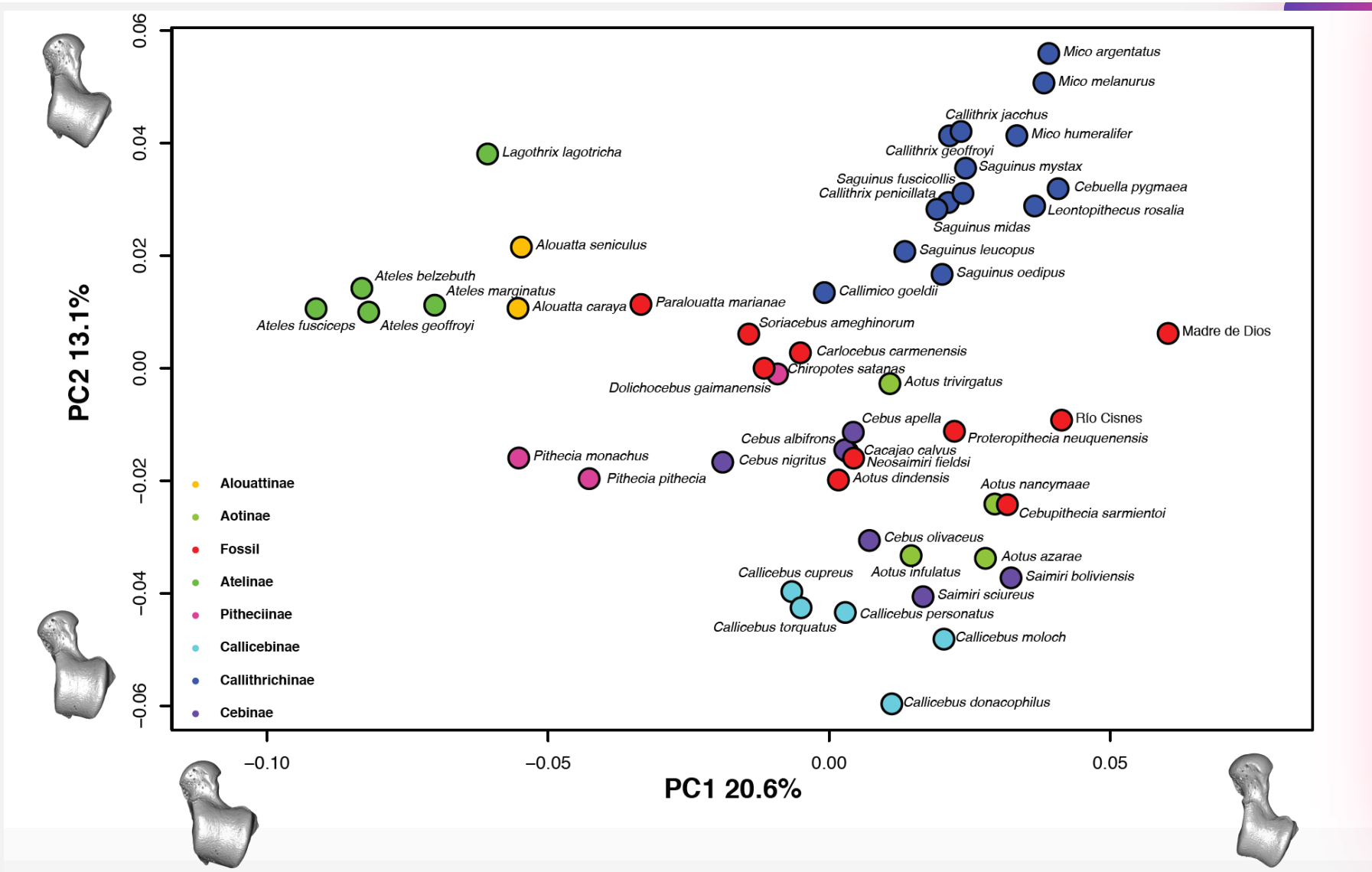
PCA: Shape



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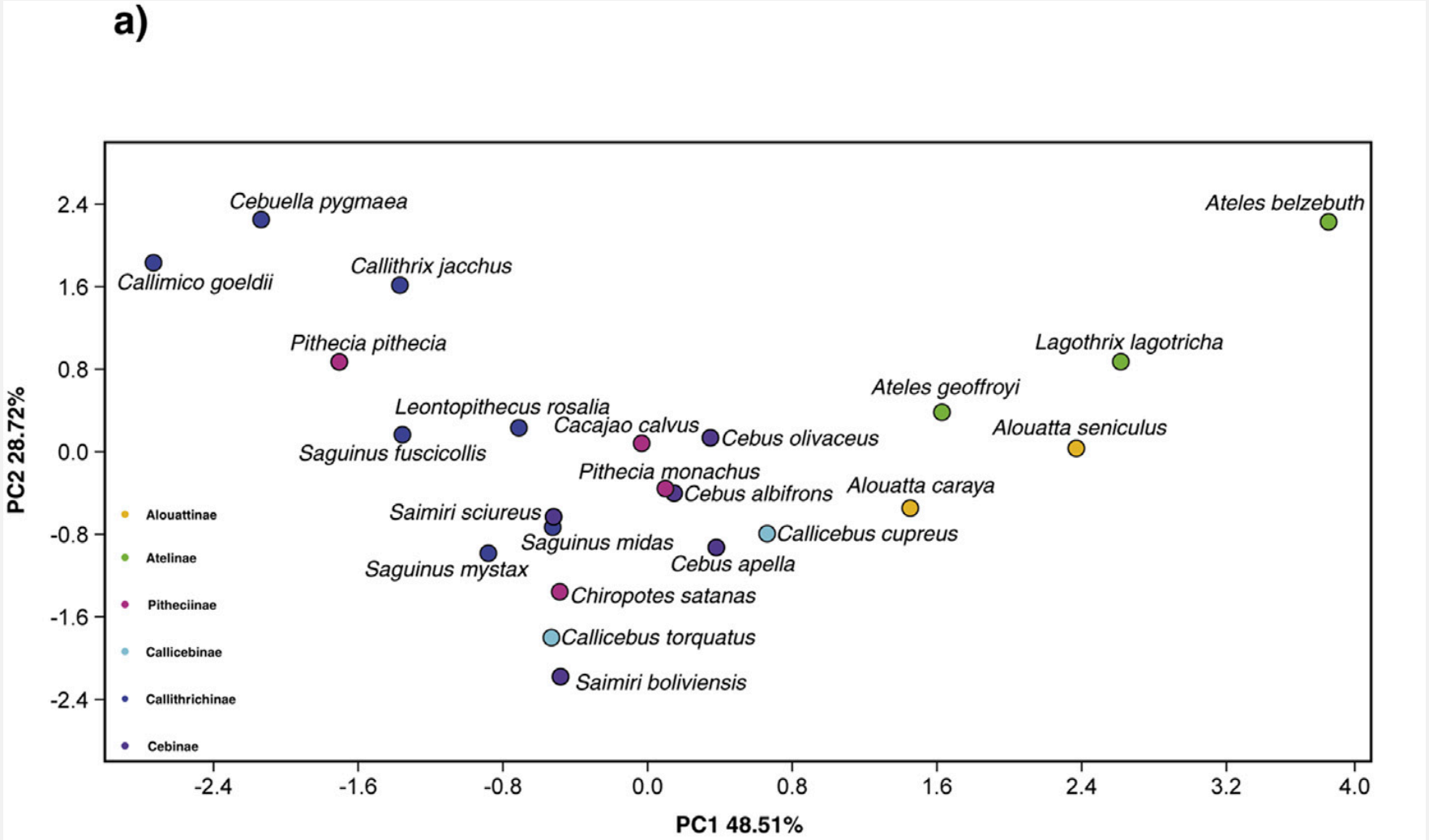
PCA: Locomotor data



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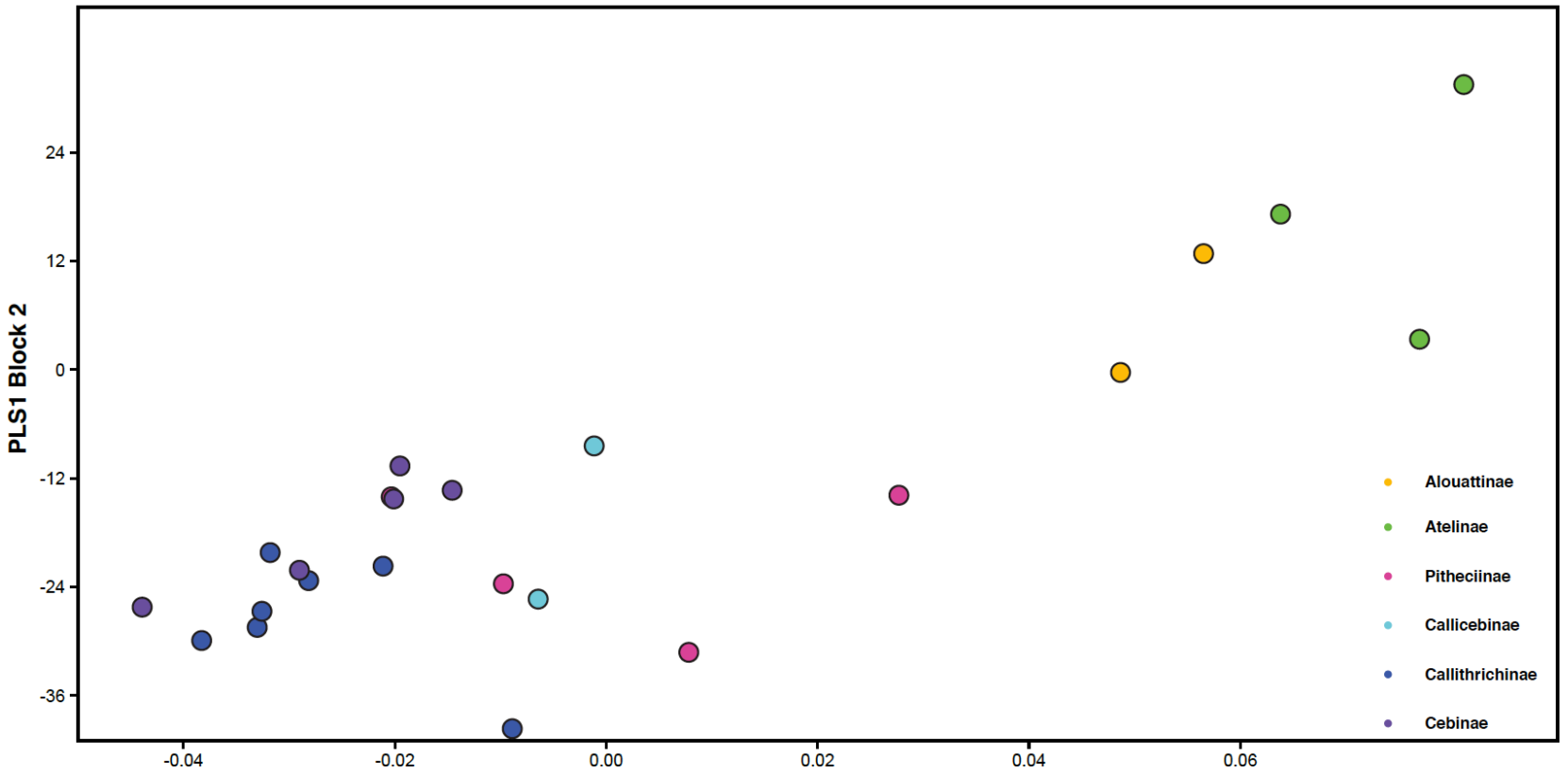
PLS: shape and locomotor data



r-PLS: 0.84; p-value: 0.0022; 10,000 permutations

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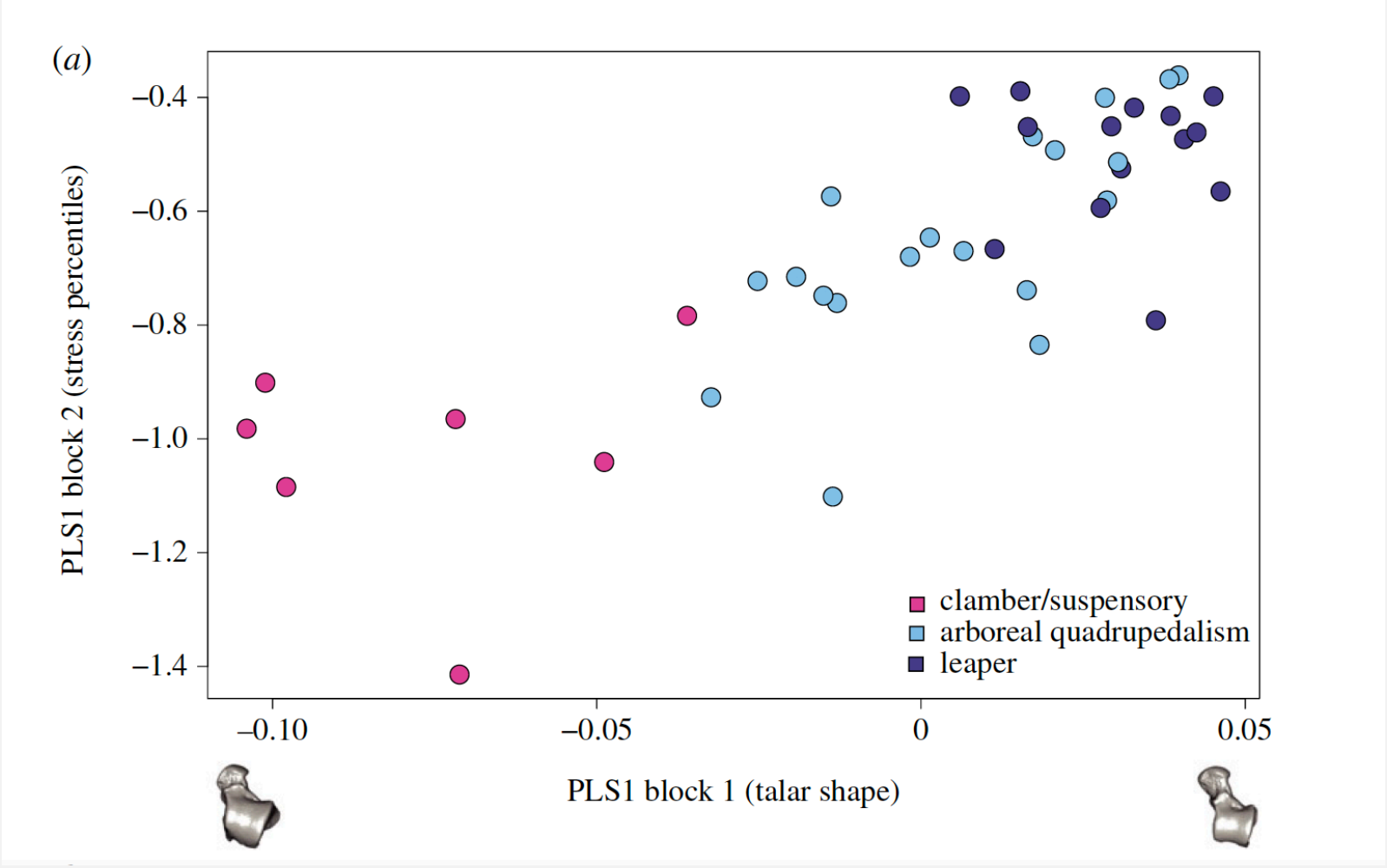
PLS: shape and stress data



r-PLS: 0.8; p-value: 0.0002; 10,000 permutations

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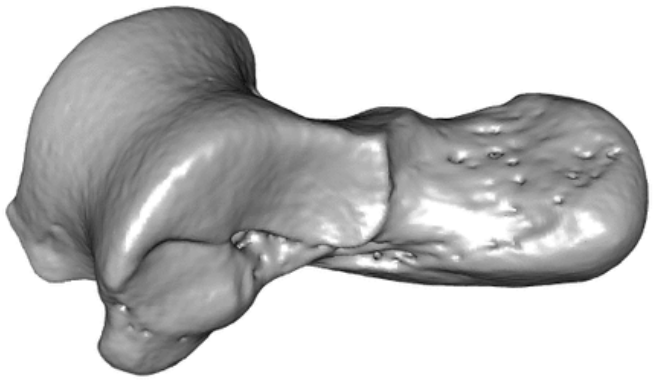

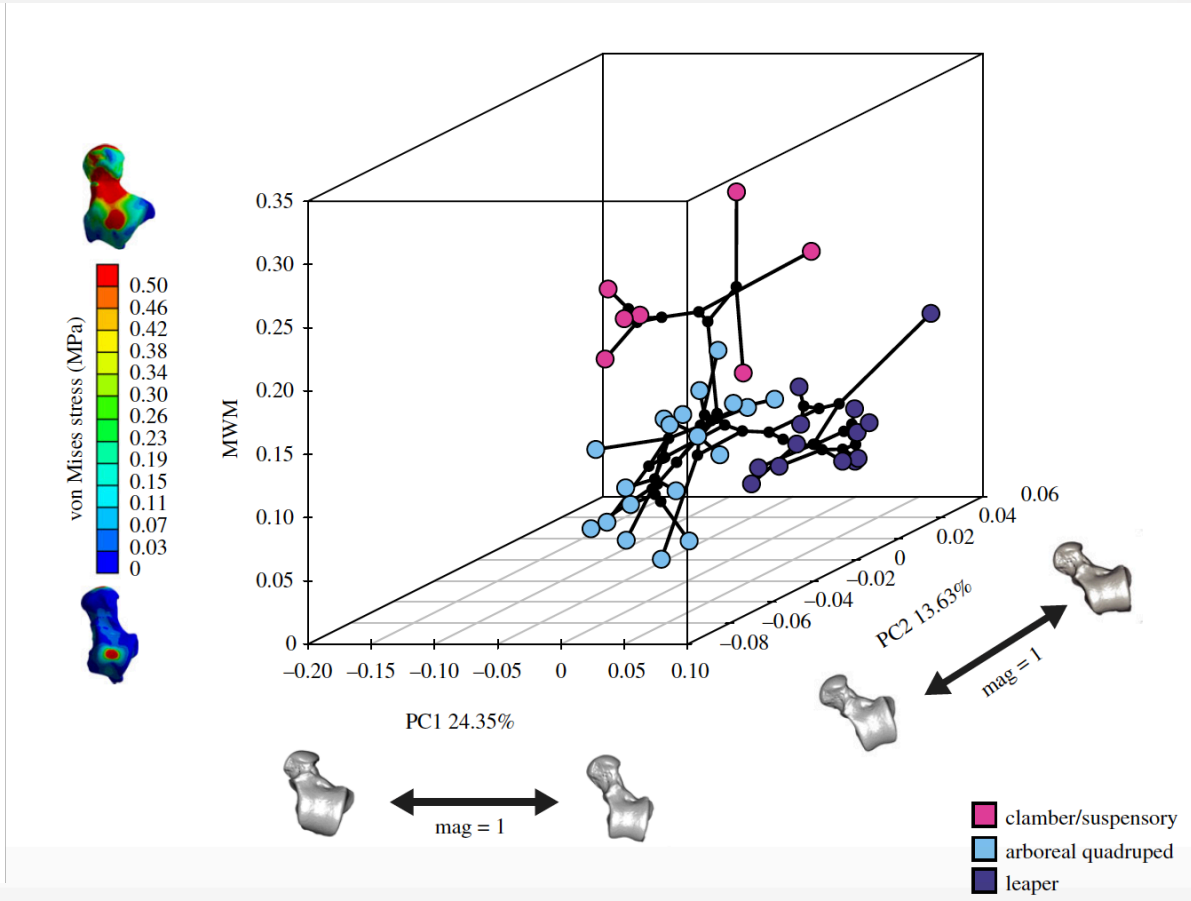

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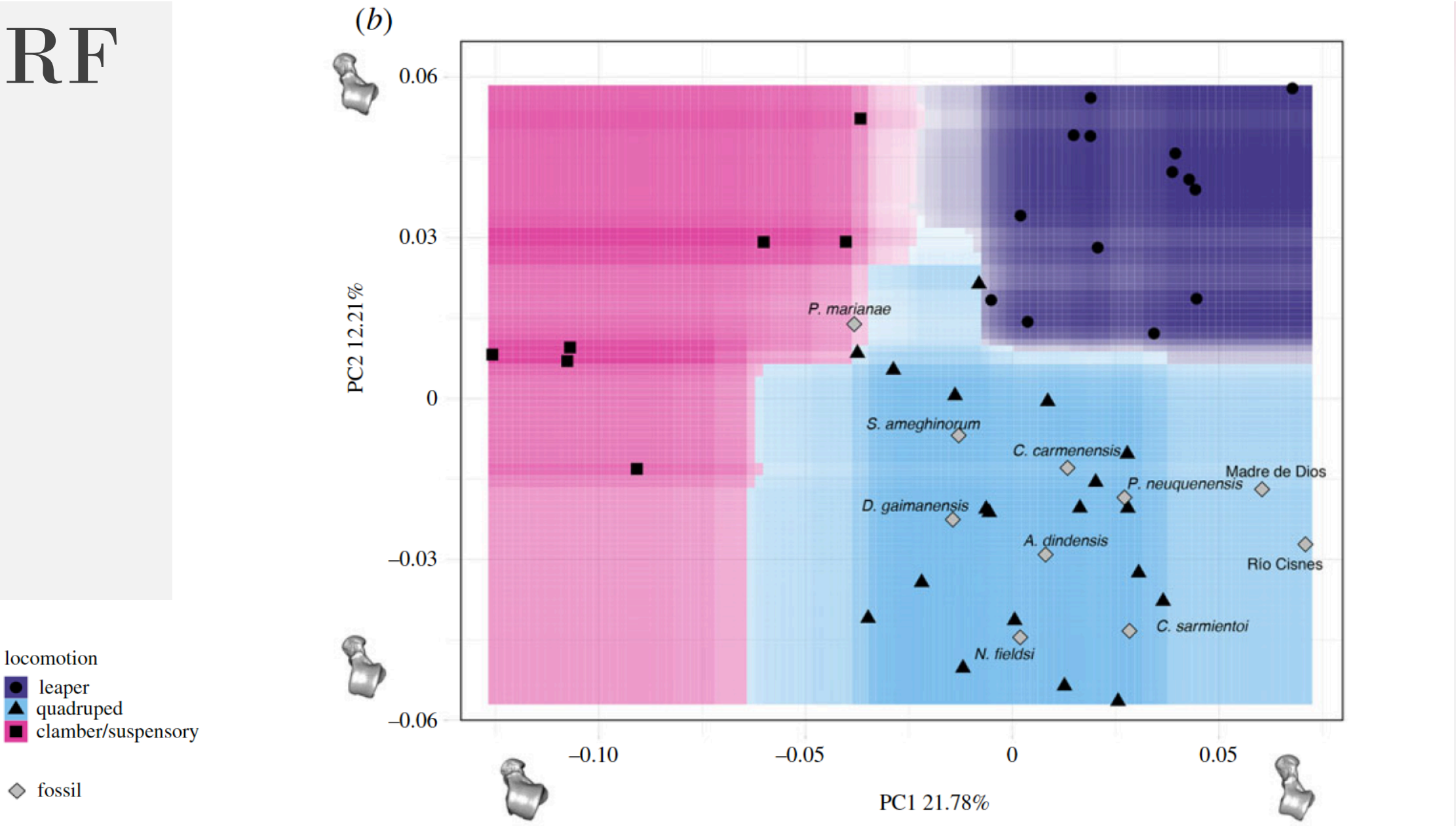
RF



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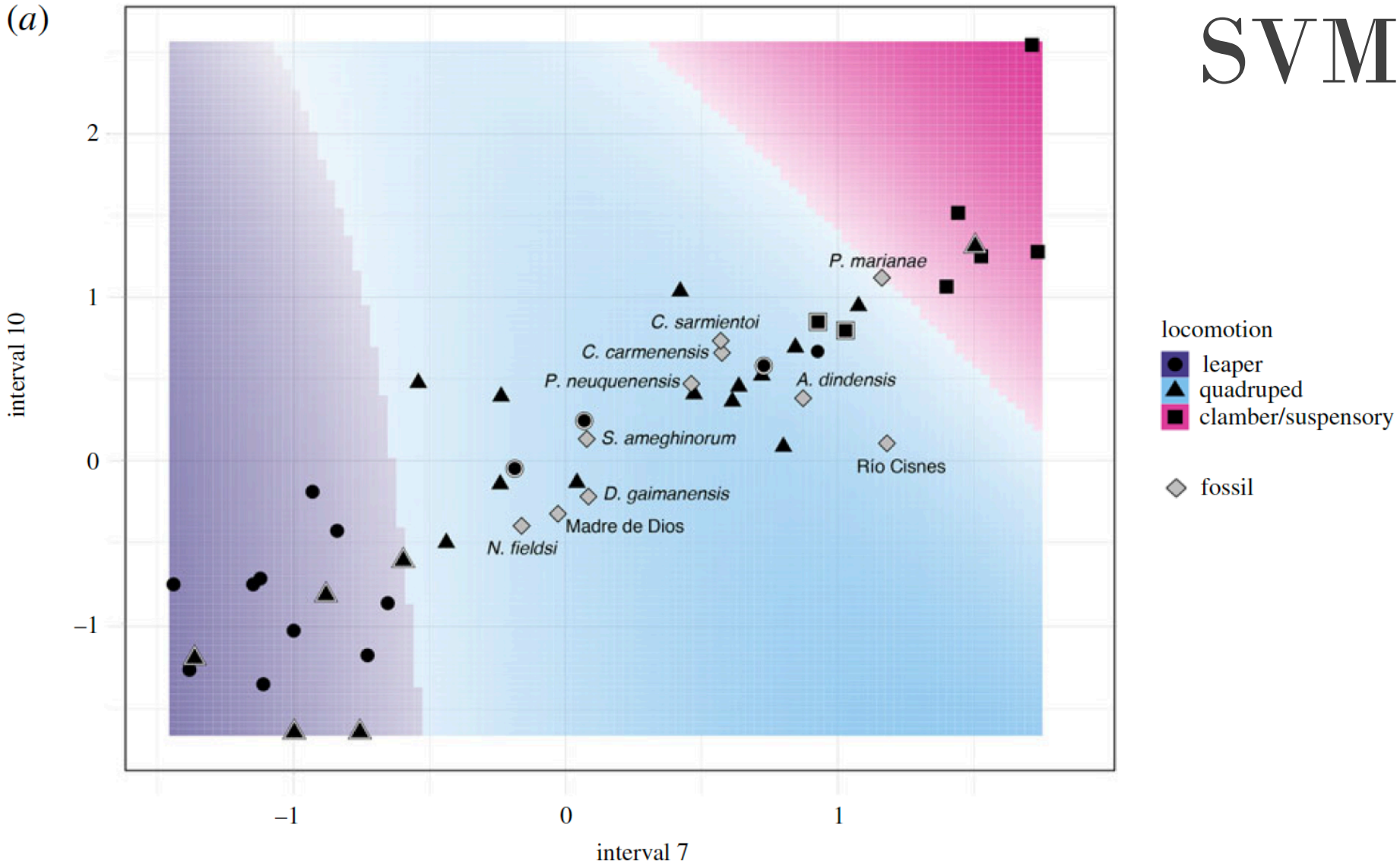
SVM



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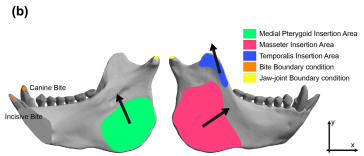
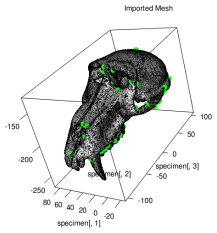
Conclusions

FEA allows addressing this issue from a mechanics point of view, while **GM** provides information about the influence of shape differences.

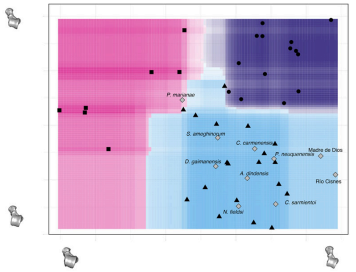
If combined in the context of **evolutionary theory (e.g. by applying PCMs**), a new framework is generated that enables testing hypotheses regarding the relative contribution of a specific function or morphology in the evolution of a particular clade.

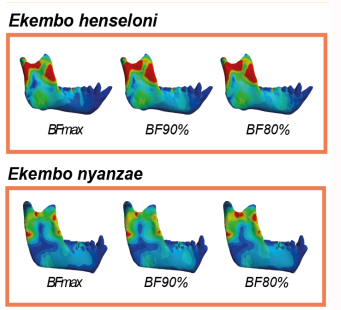
Morphometrics



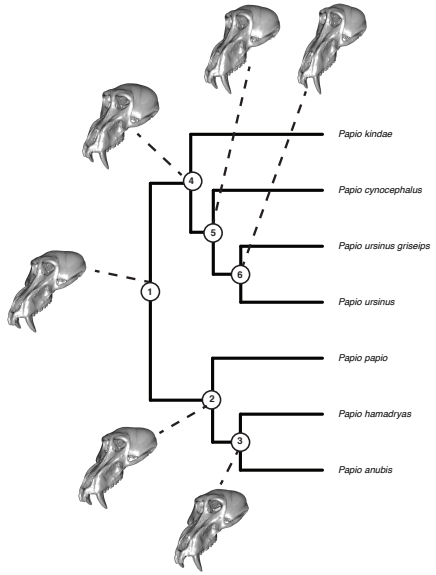


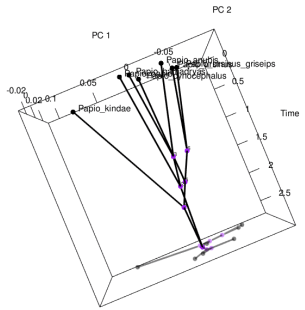
Palaeobiology

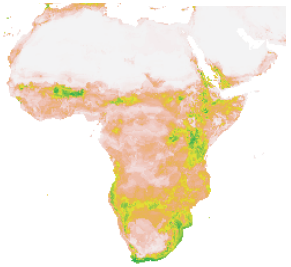




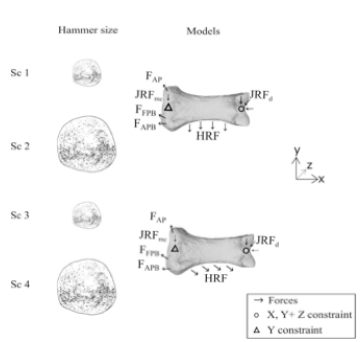
Primate evolution

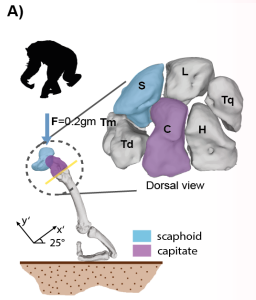


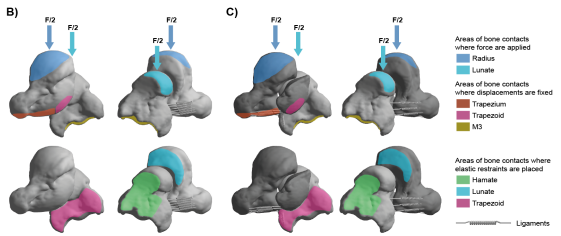




Biomechanics

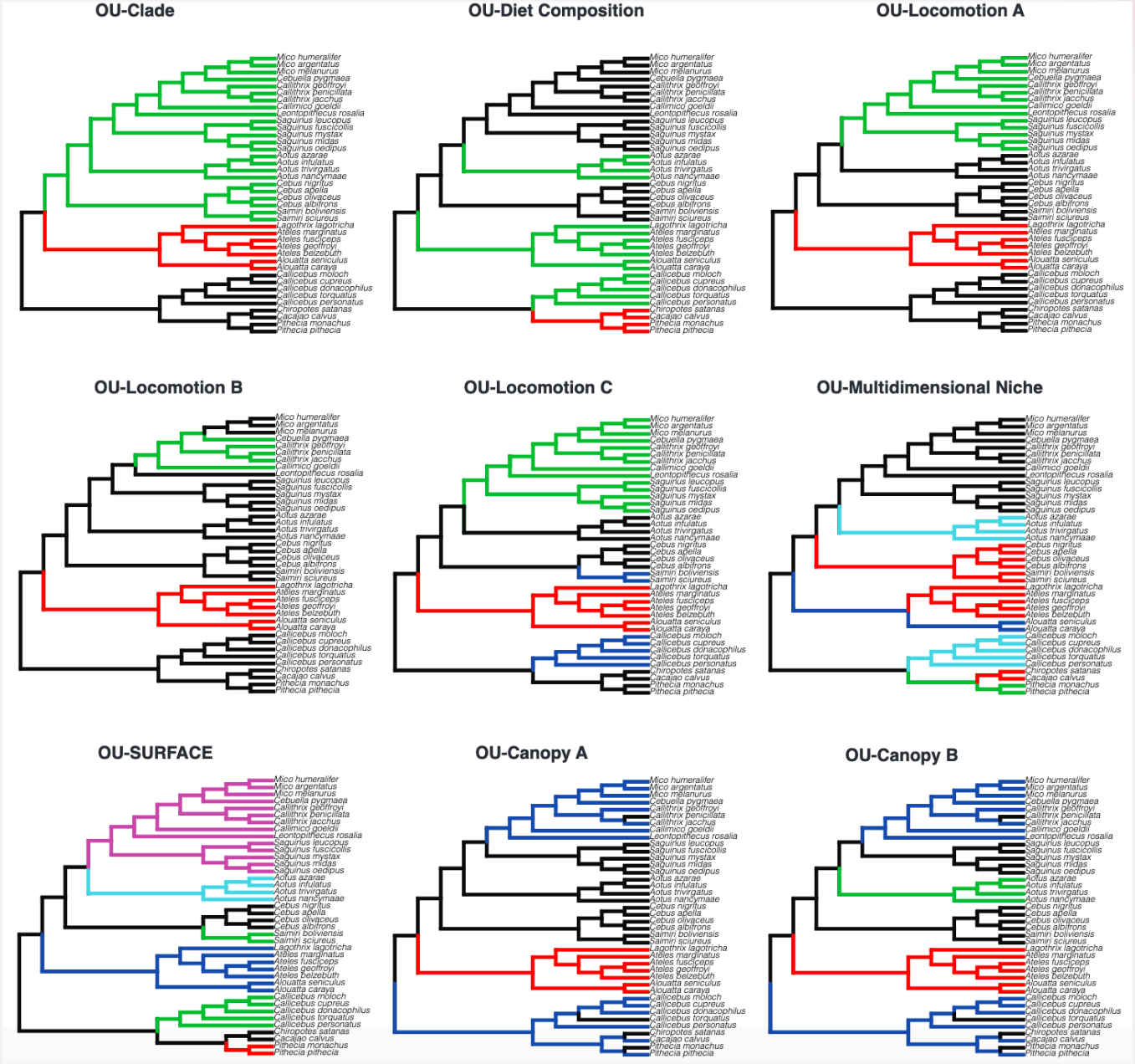






Palaeoecology

Evolutionary modelling



Püschel, T. A., Gladman, J. T., Bobe, R. & Sellers, W. I. The evolution of the platyrrhine talus: A comparative analysis of the phenetic affinities of the Miocene platyrrhines with their modern relatives. *Journal of Human Evolution* **111**, 179–201 (2017).

Thank you!
and to all my collaborators

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