Armored ‘dillos: Structural Performance of Osteoderms

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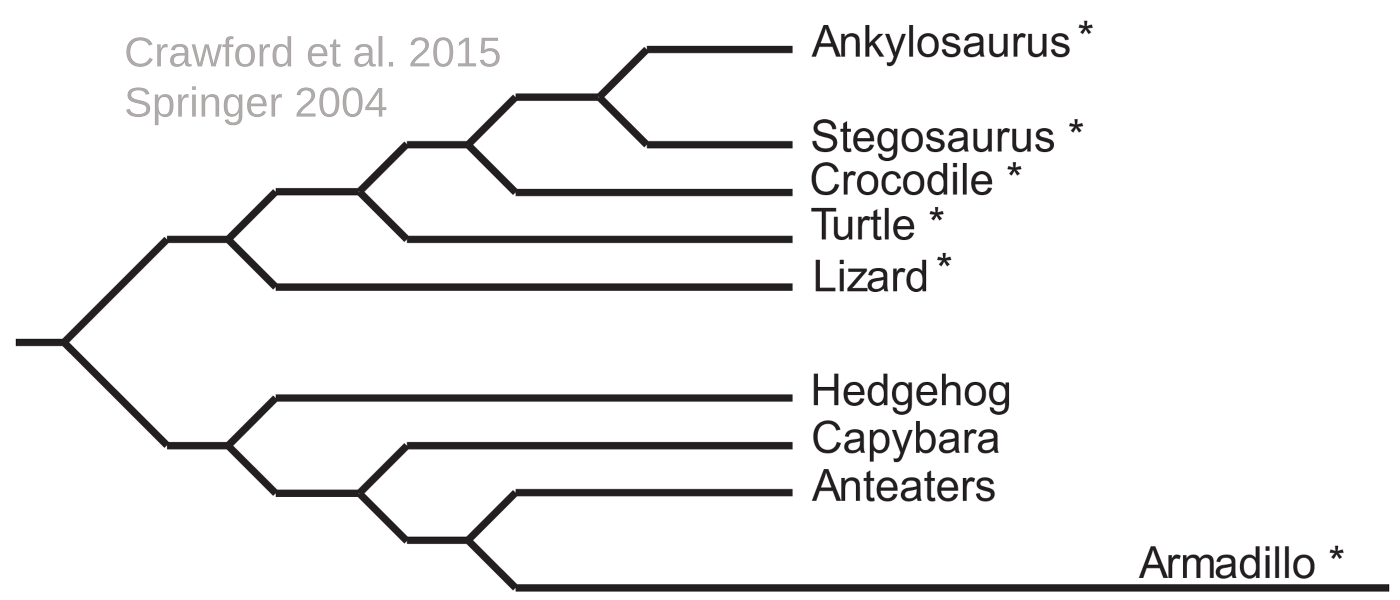
Introduction

Armor
- Morphological multifunctional adaptation[1,2]

Armadillo carapace (Fig 1)
- Tessellated osteoderm
  - **Midsection**: triangular tile[3]
  - **Pectoral** and **pelvic**: hexagonal tile[3]

What affects armor performance?
- Composition, geometry, and hard/soft synergism[4]



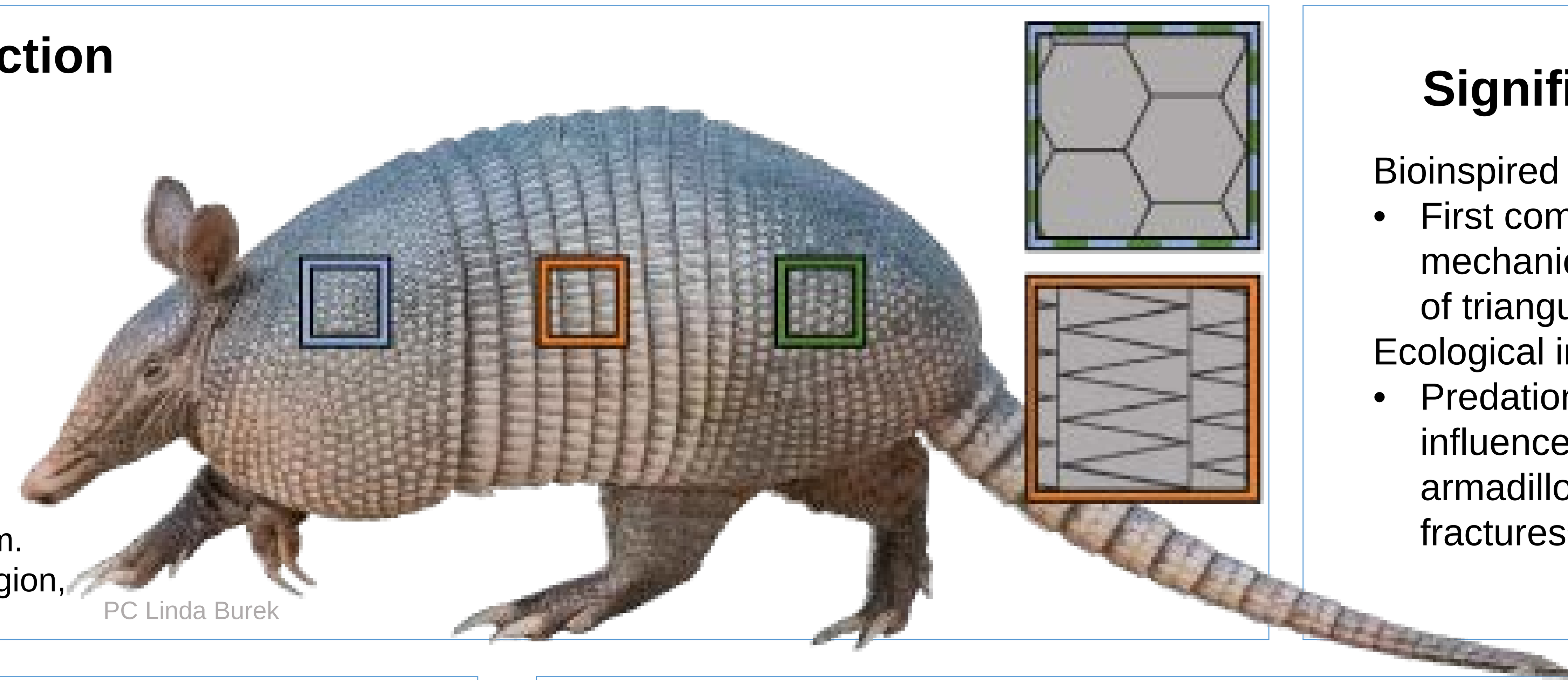


Figure 1. Armadillos are only group of mammals to have dermal osteoderm. Armadillo carapace has hexagonal tile structure in **pectoral** and **pelvic** region, and triangular tile structure in **midsection**. * indicates species has osteoderm

Significance

Bioinspired design
- First composition and mechanical evaluation of triangular tiles

Ecological insight
- Predation risk may be influenced by armadillo carapace fractures[5]

Composition

Hypothesis: *Armor tiles in midsection will be more mineralized than tiles in the pectoral and pelvic region*

Approach: Bone ash method to compare material composition for the three body sections (Fig 2)

Figure 2. Armor tiles will be ashed in muffle furnace

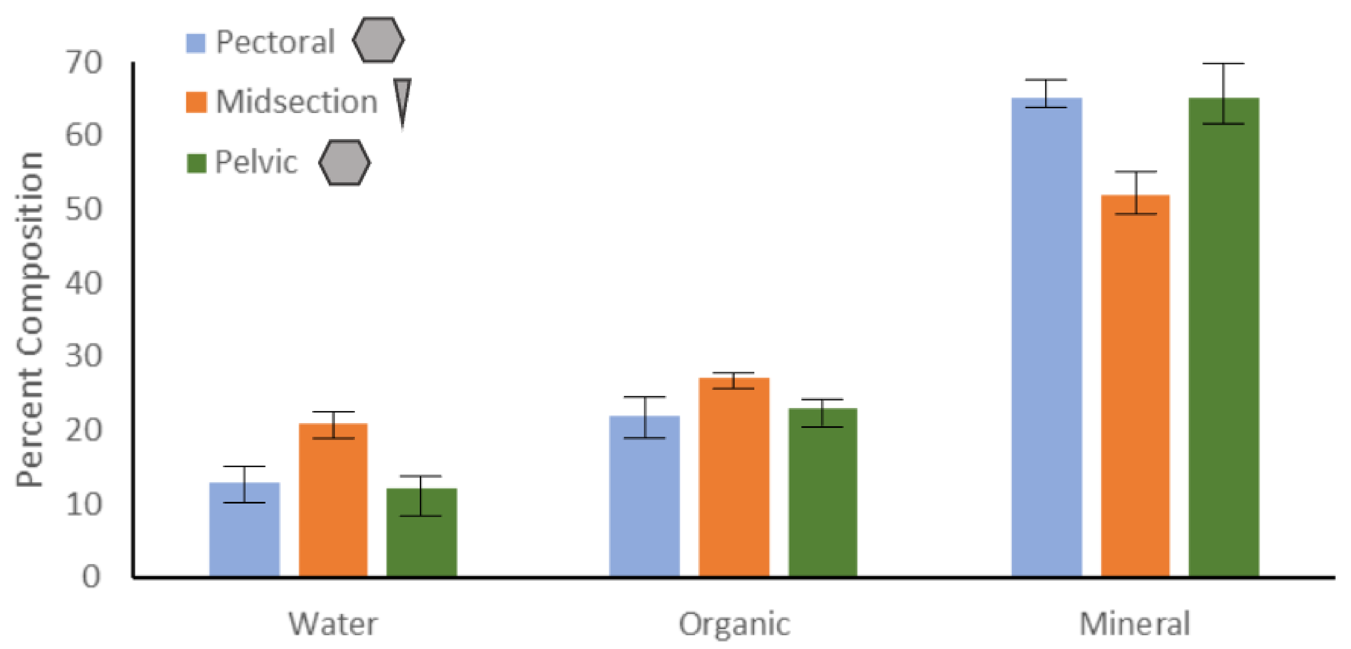


Figure 3. Predicted average water, organic and mineral content of pectoral, pelvic, and midsection from bone ashing

Geometry

Hypothesis: *3D printed hexagonal tiles will be more resistant to puncture than 3D printed triangular tile*

Approach: Puncture tests on 3D printed hexagonal and triangular models (Fig 4 & 5)

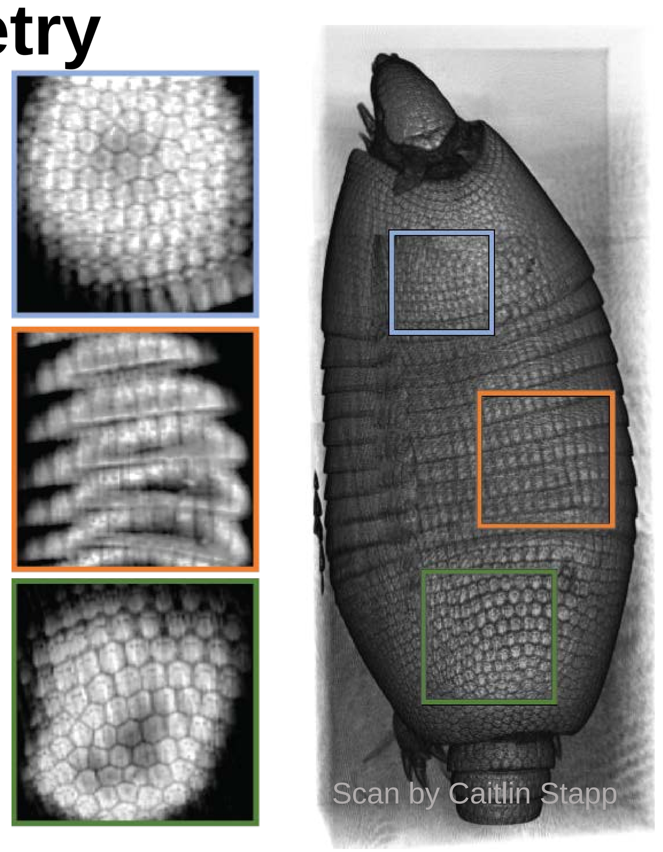
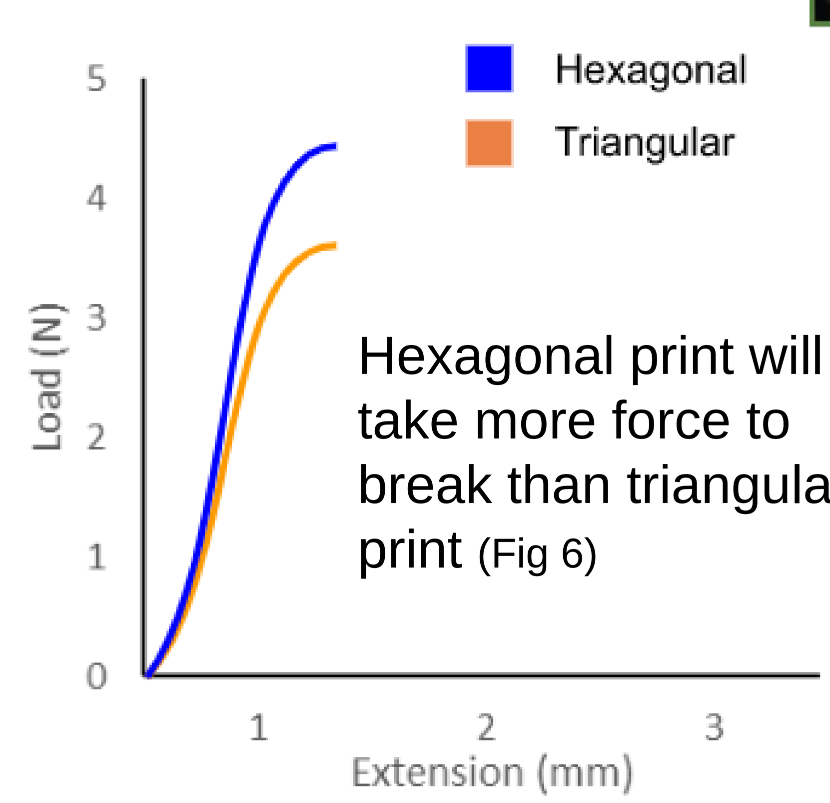


Figure 4. Full body CT (right) and cross-sectional image of tile geometry (left)



Hexagonal print will take more force to break than triangular print (Fig 6)

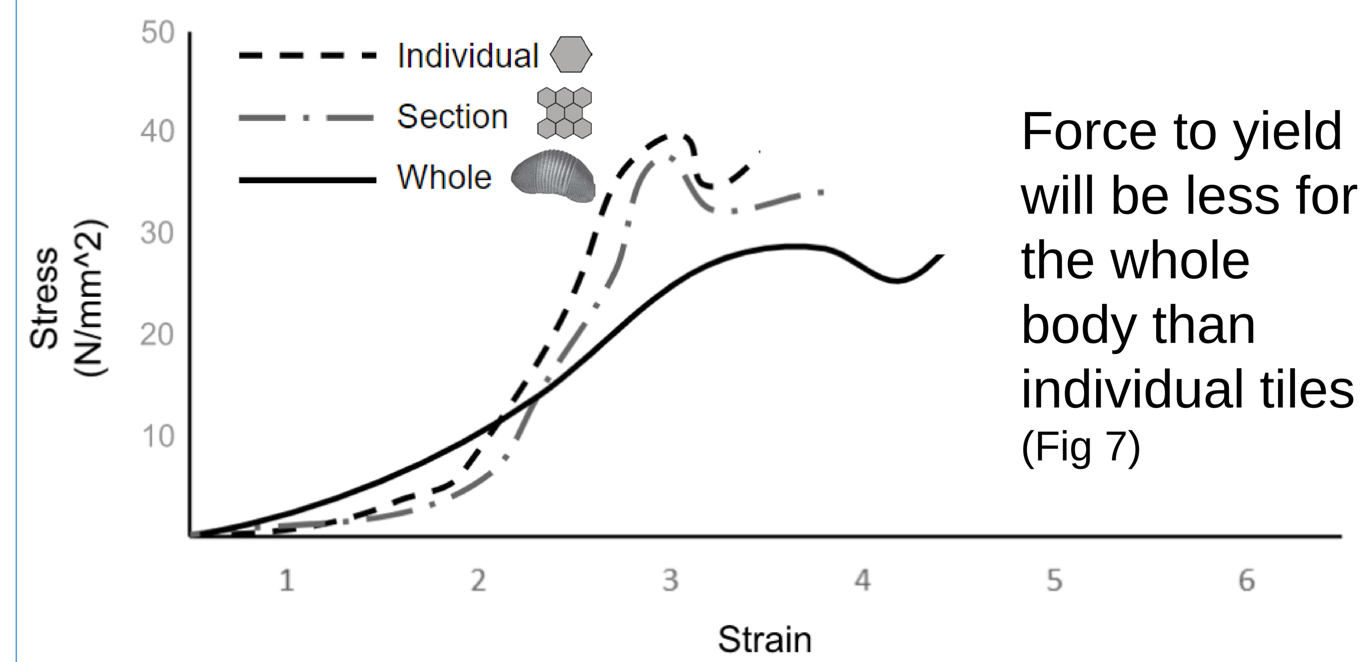
Figure 6. Predicted load-extension curve and for hexagonal and triangular 3D prints

Figure 5. Instron Material Tester

Armor & Soft Tissue Synergy

Hypothesis: *Osteoderm attached to soft tissues will be more puncture resistant than osteoderm not attached to soft tissues*

Approach: Puncture tests on individual tiles, a section of tiles, and a fully-intact osteoderm (Fig 7)

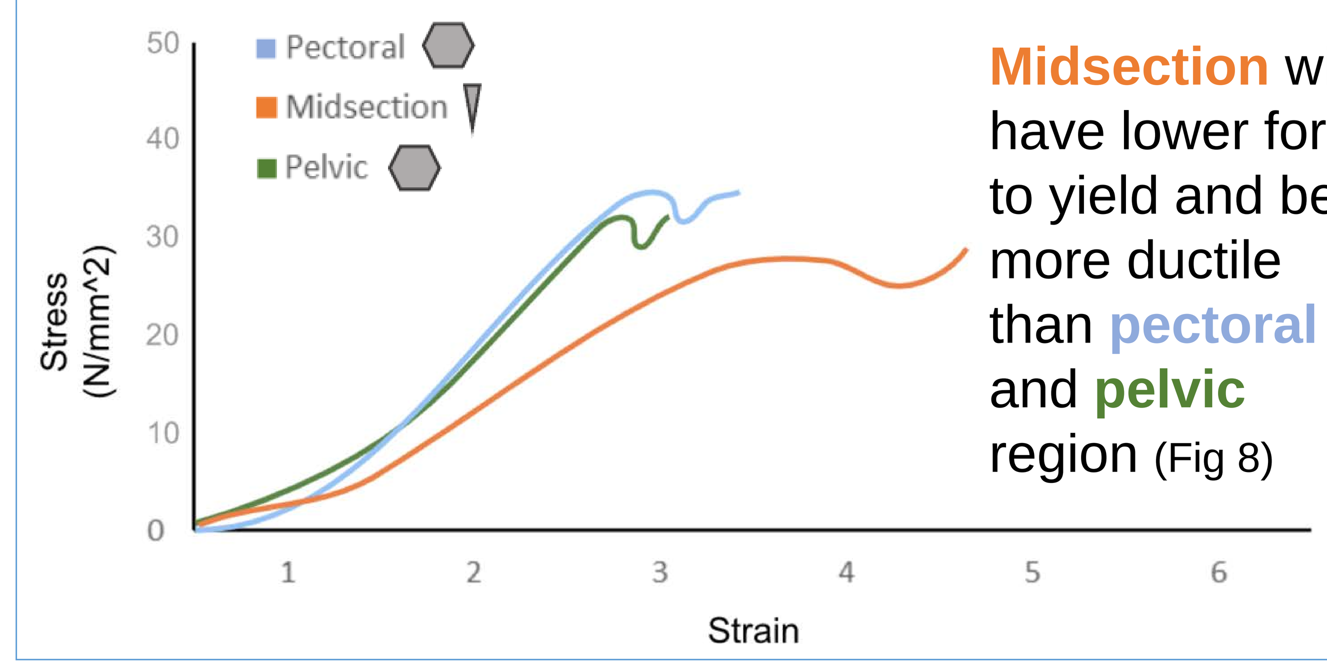


Force to yield will be less for the whole body than individual tiles (Fig 7)

Figure 7. Predicted load-extension curve for individual tile, section of osteoderm, whole body

Hypothesis: *Midsection tiles will be more resistant to puncture than pectoral and pelvic region*

Approach: Puncture tests on tiles still intact on the body (Fig 8)



Midsection will have lower force to yield and be more ductile than **pectoral** and **pelvic** region (Fig 8)

Figure 8. Predicted load-extension for each section of body (pectoral, pelvic, midsection)

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Citations: [1] Emlen, D. J. (2008). Annu. Rev. Ecol. Evol. Syst. 39:387–413. [2] Stankowich, T. and Campbell, L. A. (2016). Evol. 70:1501–1511. [3] Chen, I. H., Kiang, J. H., Correa, V., Lopez, M. I., Chen, P.-Y., McKittrick, J. and Meyers, M. A. (2011). J. Mech. Behav. Biomed. Mater. 4:713–722. [4] Vogel, S. (2003). In Comparative Biomechanics Life's Physical World. 301-324. Oxfordshire: Princeton University Press. [5] Stapp, C. (2021). Master thesis, California State University, Long Beach.

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