Skeletal Mechanics in Biological Anthropology

Class meets Mondays Periods 7-9 (1:55-4:55 PM) in TUR B304

Course materials accessed via Canvas: <u>https://lss.at.ufl.edu/</u>

<u>Instructor</u>: David Daegling, Department of Anthropology, 294-7603. <u>daegling@ufl.edu</u> Office Hours: M 12:30-1:30 PM; R 1:00 – 3:00.

<u>Prerequisites</u>: ANG 5525 Human Osteology and Osteometry and ANG 6583 Primate Functional Morphology or ANG 6740 Advanced Techniques in Forensic Anthropology

<u>Course Objectives</u>: Inference of past behaviors and adaptations from skeletal remains is crucial to the fields of bioarchaeology, functional morphology, forensic anthropology and human paleontology. This course examines the mechanical influences on skeletal morphology from the perspectives of growth, allometry and evolution. Analytical techniques for describing and inferring the mechanical behavior of bones are emphasized. Quantitative skills learned in this course include 1) modeling bone behavior at the tissue and structural level, 2) predicting physiological response of bone to load histories, 3) determination of scaling effects on skeletal form and composition and 4) consequences of ontogenetic shifts in skeletal development in a comparative evolutionary framework.

Course Requirements: Your grade will be based on the following:

- 1. Weekly problem sets to be completed outside of class (50%)
- 2. 10 in-class quizzes (30%)
- 3. Analysis and critique of supplementary readings (10%)
- 4. Attendance and participation (10%)

<u>Policies</u>: Quizzes missed due to late arrival or unexcused absences (i.e., other than medical or family emergency) cannot be made up. Problem sets submitted after stated deadlines are subject to half-credit grade reduction. Smart phones must be silenced or turned off. Plagiarism in any form is subject to university policy as outlined by the Dean of Students Office (http://www.dso.ufl.edu/judicial/academic.htm). Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation. Students experiencing personal problems that are interfering with their academic performance are encouraged to contact the University Counseling Center (301 Peabody Hall, 392-1575), Student Mental Health (Student Health Care Center, 392-1171), or Sexual Assault Recovery Services (Student Health Care Center, 392-1161).

<u>Text</u>:

- Martin RB, Burr DB, Sharkey NA (1998) *Skeletal Tissue Mechanics*. New York: Springer. [STM]
- Supplementary Readings [SR#]:
- 1. Antón SC. 1996. Tendon-associated bone features of the masticatory system in Neandertals. *Journal of Human Evolution* 31: 391-408.
- Barak MM, Lieberman DE, Raichlen D, Pontzer H, Warrener AG, et al. 2013. Trabecular Evidence for a Human-Like Gait in *Australopithecus africanus*. *PLoS ONE* 8(11): e77687. doi:10.1371/journal.pone.0077687
- Bouvier M, Hylander WL. 1981. The relationship between split-line orientation and in vivo bone strain in galago (*G. crassicaudatus*) and macaque (*Macaca mulatta* and *M. fascicularis*) mandibles. *American Journal of Physical Anthropology* 56: 147-156.
- Bouvier M, Hylander WL. 1996. The mechanical or metabolic function of secondary osteonal bone in the monkey *Macaca fascicularis*. Archives Oral Biology 41:941-950.
- 5. Burr DB. 2011. Why bones bend but don't break. *J Musculoskelet Neuronal Interact* 11: 270-285.
- 6. Carter DR, Wong M, Orr TE. 1991. Musculoskeletal ontogeny, phylogeny, and functional adaptation. *J Biomech* 24(Suppl. 1): 3-16.
- 7. Cerroni AM, Tomlinson GA, Turnquist JE, Grynpas MD. 2000. Bone mineral density, osteopenia, and osteoporosis in the rhesus macaques of Cayo Santiago. *American Journal of Physical Anthropology* 113:389-410.
- 8. Currey JD. 2003. The many adaptations of bone. *Journal of Biomechanics* 36:1487-1495.
- 9. de Jong WC, van Ruijven LJ, Brugman P, Langenbach GEJ. 2013. Variation of the mineral density in cortical bone may serve to keep strain amplitudes within a physiological range. *Bone* 55:391-399.
- 10. Erickson GM, Catanese J, Keaveny TM. 2002. Evolution of the biomechanical material properties of the femur. *Anatomical Record*, 268:115-124.
- 11. Gibson VA, Stover SM, Gibeling JC, Hazelwood SJ, Martin RB. 2006. Osteonal effects on elastic modulus and fatigue life in equine bone. *Journal of Biomechanics* 39:217-225.

- 12. Keller TS, Lovin JD, Spengler DM, Carter DR (1985) Fatigue of immature baboon cortical bone. Journal of Biomechanics 18(4):297-304.
- 13. Lieberman DE (1996) How and why recent humans grow thin skulls: experimental data on systemic cortical robusticity. *American Journal of Physical Anthropology* 101: 217-236.
- 14. Lovejoy CO, Heipl KG & Burstein AH (1973) The gait of Australopithecus. American Journal of Physical Anthropology 38:757-780.
- 15. Pearson, O. M., & Lieberman, D. E. (2004). The aging of Wolff's "law": ontogeny and responses to mechanical loading in cortical bone. American journal of physical anthropology, 125(S39), 63-99.
- Rubin, C., Turner, A. S., Bain, S., Mallinckrodt, C., & McLeod, K. (2001). Anabolism: Low mechanical signals strengthen long bones. Nature, 412(6847), 603-604.
- 17. Ruff CB, Runestad JA (1992) Primate limb bone structural adaptations. *Annual Review of Anthropology* 21: 407-433.
- Skedros, J. G., Keenan, K. E., Williams, T. J., & Kiser, C. J. (2013). Secondary osteon size and collagen/lamellar organization ("osteon morphotypes") are not coupled, but potentially adapt independently for local strain mode or magnitude. *Journal of Structural Biology* 181:95-107.
- 19. Sun Z, Lee E, Herring SW. 2004. Cranial sutures and bones: Growth and fusion in relation to masticatory strain. Anat. Rec 276A:150–161.
- 20. Tommasini SM, Nasser P, Schaffler MB, Jepsen KJ. (2002) Relationship between bone morphology and bone quality in male tibias: implications for stress fracture risk. *Journal of Bone and Mineral Research* 20: 1372-1380.
- Trinkaus E, Churchill SE, Villemeur I, Riley KG, Heller JA, Ruff CB. 1991. Robusticity *versus* shape: the functional interpretation of Neandertal appendicular morphology. *Journal of the Anthropological Society of Nippon*. 99, 257-278.
- 22. Yeni YN, Fyhrie DP. 2002. Fatigue damage-fracture mechanics interaction in cortical bone. *Bone* 30:509-514.
- 23. Zioupos P, Currey JD. 1998. Changes in the stiffness, strength, and toughness of human cortical bone with age. *Bone* 22:57-66.

Course Schedule:

Week 1 (1/11)	Force and Energy
Week 2	Free-body analysis, Statics
(1/25)	Readings: STM Chapter 1
Week 3 (2/1)	Skeletal biology: Tissues Readings: STM Chapter 2; SR 14
Week 4	Skeletal biology: Remodeling
(2/8)	Readings: STM Chapter 3; SR 3
Week 5 (2/15)	Elastic properties and the stress tensor Readings: STM sections 4.1 - 4.2 (pp 127-134); SR 4, 18
Week 6	Essentials of structural mechanics
(2/22)	Readings: STM section 4.3 (pp 134-143); SR 8
Week 7	Material properties of cortical and cancellous bone
(3/7)	Readings: STM sections 4.4 – 4.7 (pp 143 - 178); SR 17, 21
Week 8	Fracture and fatigue
(3/14)	Readings: STM Chapter 5; SR 2, 9
Week 9	Functional Adaptation I: Wolff's Law
(3/21)	Readings: STM sections 6.1 – 6.4 (pp 225-245); SR 11, 12, 22
Week 10	Functional Adaptation II: Competing models
(3/28)	Readings: STM sections 6.5 – 6.8 (pp 245- 272); SR 15, 20
Week 11	Cartilage and Joints
(4/4)	Readings: STM Chapter 7; SR 5, 13, 16
Week 12	Ligament and Tendon
(4/11)	Readings: STM Chapter 8; SR 19
Week 13 (4/18)	Mechanobiology of growth and evolutionary adaptation Readings: SR 1, 6, 10, 23

Notes on the course grading scheme

Problem Sets:

Problem sets are accessed on the Canvas course page. These are to be submitted online prior to the beginning of class each week. Showing how you arrived at problem solutions is essential. Submitting answers without such demonstration earns no credit.

Supplementary Readings Analysis & Critique:

During designated class times, you will answer questions from assigned articles individually on discussion boards, then convene as a group to seek a consensus to the question(s) raised. This will be followed by an in-class discussion with the instructor.

Quizzes:

These are unannounced and are given at the beginning of class. Missed quizzes cannot be made up unless you were sick or have a family emergency.

Attendance and Participation:

If you are punctual, attend every class meeting and participate non-frivolously in class activities you can expect to get full credit for this part of the course grade.