ANG 6524 / ANT 4930 **Fall 2022**

Skeletal Mechanics in Biological Anthropology

Class meets Tuesdays Period 8 - 10 (3:00 PM – 6:00 PM) in RNK 0220

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

Instructor: David Daegling, Department of Anthropology, 294-7603. daegling@ufl.edu
Office: TUR B376. Office Hours: T 10:30 - Noon; W 1:00 – 3:00 and by appointment.

Prerequisites: ANT 4525/ANG 5525 Human Osteology and Osteometry recommended.

Course Objectives: 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) developmental influences on skeletal evolution in a comparative framework.

Student Learning Outcomes: Successful completion of this course will allow you to:

- Assess bone quality as it relates to functional activity
- Identify types of bone histologically
- Evaluate variables for prediction of bone fracture
- Calculate stresses and strains in bone, joints, muscle and tendon
- Discriminate between adaptive and historical factors in skeletal evolution

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

1. Weekly problem sets to be completed outside of class (50%)
2. In-class quizzes (30%)
3. Participation and discussion of supplementary readings (10%)
4. Final Exam (10%)

The percentage of points earned (your total points earned divided by the total points possible) determines your final grade. For information on grade points see UF's Grades and Grading Policies page.

Grades will be assigned by the following scheme:

A	> 90%
A-	87 – 90%
B+	84 – 87%
B	80 – 84%
B-	77 – 80%
C+	74 – 77%
C	67 – 74%
C-	60 – 67%
D+	57 – 60%
D	54 – 57%
D-	50 – 54%
E	< 50%

Course Policies

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 can only earn up to half the assignment credit, unless documentation is provided for illness or medical or family emergency.

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 with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Students experiencing personal problems that are interfering with their academic performance are encouraged to contact UF's Counseling and Wellness Center (3190 Radio Rd., 392-1575) or U Matter We Care (352-294-CARE (2273)).

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at gatorevals.aa.ufl.edu/public-results/ .

There are no materials and supplies fees for this course.

Additional notes and policies on the course assignments

All assignment deadlines are posted in Canvas.

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 demonstration earns no credit. Copying problem solutions of others or allowing such copying earns zero points and is subject to additional penalties as allowed by university policy.

Supplementary Readings Analysis & Critique: During designated times, you will answer question prompts based on assigned articles on discussion boards, followed by in-class discussion.

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.

Final Exam: This is given as a "take-home" exam. In the event of outstanding collective work the instructor may cancel this assignment and award points in full to all students.

Course Materials

Text:

Martin RB, Burr DB, Sharkey NA, Fyhrie DP (2015) *Skeletal Tissue Mechanics*. New York: Springer. [STM]

Supplementary Readings [SR#]:

1. Aiello BR, Iriarte-Diaz J, Blob RW, Butcher MT, Carrano MT, Espinoza NR, Main RP, Ross CF. 2015. Bone strain magnitude is correlated with bone strain rate in tetrapods: implications for models of mechanotransduction. *Proc. R. Soc. B* 282: 20150321

2. Antón SC. 1996. Tendon-associated bone features of the masticatory system in Neandertals. *Journal of Human Evolution* 31: 391-408.

3. 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.

4. Brand, RA. 2005. Joint contact stress: a reasonable surrogate for biological processes? *The Iowa Orthopaedic Journal*, 25, 82.

5. Butler DL, Kay MD, Stouffer DC. 1986. Comparison of material properties in fascicle-bone units from human patellar tendon and knee ligaments. *Journal of Biomechanics* 19: 425-432.

6. Carter DR, Van der Meulen MCH, Beaupre GS. 1996. Mechanical factors in bone growth and development. *Bone,* 18(1), pp.S5-S10.

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. Dechow PC, Wang Q, Peterson J. 2010. Edentulation alters material properties of cortical bone in the human craniofacial skeleton: functional implications for craniofacial structure in primate evolution. *The Anatomical Record* 293: 618-629.

10. 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.

11. Erickson GM, Catanese J, Keaveny TM. 2002. Evolution of the biomechanical material properties of the femur. *Anatomical Record*, 268:115-124.

12. Frost HM. 1988. Vital biomechanics: proposed general concepts for skeletal adaptations to mechanical usage. *Calcified Tissue International*, 42(3), pp.145-156.

13. Gingerich, P. D. (1979). The human mandible: lever, link, or both?. American journal of physical anthropology, 51(1), 135-137.

14. Jungers WL. 1988. Relative joint size and hominoid locomotor adaptations with implications for the evolution of hominid bipedalism. *Journal of Human Evolution*, 17: 247-265.

15. Keller TS, Lovin JD, Spengler DM, Carter DR. 1985. Fatigue of immature baboon cortical bone. *Journal of Biomechanics* 18(4):297-304.

16. 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.

17. Lieberman, D. E., Polk, J. D., & Demes, B. (2004). Predicting long bone loading from cross-sectional geometry. *American Journal of Physical Anthropology* 123(2), 156-171.

18. Lovejoy CO, Heipl KG, Burstein AH (1973) The gait of *Australopithecus*. *American Journal of Physical Anthropology* 38:757-780.

19. Martin, R. B. (2003). Fatigue microdamage as an essential element of bone mechanics and biology. Calcified Tissue International, 73(2), 101-107.

20. McFarlin SC, Terranova CJ, Zihlman AL, Enlow DH, Bromage TG. 2008. Regional variability in secondary remodeling within long bone cortices of catarrhine primates: the influence of bone growth history. *Journal of Anatomy*, 213: 308–324.

21. Ozcivici E, Luu YK, Adler B, Qin YX, Rubin J, Judex S, Rubin CT. 2010. Mechanical signals as anabolic agents in bone. *Nature Reviews Rheumatology 6:* 50-59.

22. Pearson OM, Lieberman DE. 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.

23. Rafferty KL, Herring SW, Marshall CD. 2003. Biomechanics of the rostrum and the role of facial sutures. *Journal of Morphology*, 257(1), 33-44.

24. Robling AG. 2009. Is bone's response to mechanical signals dominated by muscle forces? *Medicine and Science in Sports and Exercise*, 41:.2044.

25. Ruff CB, Runestad JA. 1992. Primate limb bone structural adaptations. *Annual Review of Anthropology* 21: 407-433.

26. Schaffler, M. B., Radin, E. L., & Burr, D. B. (1990). Long-term fatigue behavior of compact bone at low strain magnitude and rate. *Bone*, 11(5), 321-326.

27. 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(2), 95-107.

28. Skedros JG, Dayton MR, Sybrowsky CL, Bloebaum RD, Bachus KN. 2003. Are uniform regional safety factors an objective of adaptive modeling/remodeling in cortical bone? *Journal of Experimental Biology*, 206(14), 2431-2439.

29. Sun Z, Lee E, Herring SW. 2004. Cranial sutures and bones: Growth and fusion in relation to masticatory strain. *The Anatomical Record* 276A:150–161.

30. 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.

31. 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.

32. Yeni YN, Fyhrie DP. 2002. Fatigue damage-fracture mechanics interaction in cortical bone. *Bone* 30:509-514.

33. Yoshikawa T, Mori S., Santiesteban AJ, Sun TC, Hafstad E, Chen J, Burr DB. 1994. The effects of muscle fatigue on bone strain. *Journal of Experimental Biology*, 188(1), 217-233.

34. Zihlman, A. L., & Hunter, W. S. (1972). A biomechanical interpretation of the pelvis of *Australopithecus. Folia Primatologica*, 18(1-2), 1-19.

35. Zioupos P, Currey JD. 1998. Changes in the stiffness, strength, and toughness of human cortical bone with age. *Bone* 22:57-66.

36. Maynard Smith J, Savage RJ. 1959. The mechanics of mammalian jaws. *School Science Review*. 40(4):289-301.

Course Schedule:

Week 1 (8/30)	Force and Energy
Week 2 (9/6)	Statics, Lever Mechanics Readings: SR 36
Week 3 (9/13)	Free-body analysis Readings: STM Chapter 1, SR **13**
Week 4 (9/20)	Skeletal biology: Tissues Readings: STM Chapter 2; SR **18, 34**
Week 5 (9/27)	Skeletal biology: Bone metabolic activity Readings: STM sections 3.1 – 3.4; SR **8**
Week 6 (10/4)	Skeletal biology: Remodeling Readings: STM sections 3.5 – 3.8; SR **12**
Week 7 (10/11)	Elastic properties and the stress tensor Readings: STM sections 7.1 – 7.2; SR **3**, 20, **28**
Week 8 (10/18)	Essentials of structural mechanics and material properties Readings: STM section 7.3 – 7.8; SR **9**, **10**
Week 9 (10/25)	Fracture and fatigue Readings: STM Chapter 8; SR **17**, **24**, 25, 33
Week 10 (11/1)	Functional adaptation I: Wolff's Law Readings: STM sections 6.1 – 6.4; SR 7, 15, **26**, **30**, 32
Week 11 (11/8)	Functional adaptation II: Signals Readings: STM section 6.5; SR **22**, 31
Week 12 (11/15)	Functional adaptation III: Models Readings: STM sections 6.6 – 6.8; SR **1**, **27**, 28
Week 13 (11/22)	Ligament and Tendon Readings: STM Chapter 4; SR **6**, **19**, **21**
Week 14 (11/29)	Cartilage and Joints Readings: STM Chapter 5; SR **2**, **5**
Week 15 (12/6)	Scaling; Bone in evolutionary perspective Readings: SR 4, **11**, 14, **16**, 23, 29