BIOMECHANICS

ANTH 595
THE UNIVERSITY OF TENNESSEE – FALL 2013

Instructor: Benjamin M. Auerbach, Ph.D.
Contact information:

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Class Time: Tuesdays (5:45 – 8:45 P.M.)
Class Location: 427 Hesler Biology Building
Course web site: Go to **bblearn.utk.edu** for announcements and to access the course readings.

Course Description

Biomechanics is the study of functional morphology. Broadly, in biomechanical studies, we examine the activities of organisms—from bacteria to trees to vertebrates—and attempt to understand the physical properties that allow them to engage in these behaviors. The literature in this subject is replete with examinations of the material properties of solid materials (e.g., the stiffness of wood, or the strength of bone), both statically or dynamically, as well as the movement of liquids through organisms or of organisms through liquids (including air).

This course, a graduate lecture-based seminar, focuses on the basic concepts of biomechanics and relates them to studies of vertebrates, especially humans. We start the course with a review of bone biology. Three topics are the focus for the remainder of the course: scaling relationships (allometry) & basic mechanics; statics and bone; and kinematic and energetic studies. You, as a participant in the course, are asked to relate this information to the areas of research that interest you, and to bring this into the weekly discussions of the seminar. Though this is not an engineering course, some engineering principles are introduced throughout the semester.

Course objectives

By the end of this course, you will:

- develop a firm comprehension of the general areas noted in the course description, especially bone biology, scaling, and basic mechanics
- appreciate the relationship of these topics to current biological anthropology research, including knowledge of consensus and debate within the field
- explore the application of theory to practical questions and your own research.

Prerequisite

All students enrolled must have a good understanding of osteology and basic bone biology. Additional backgrounds in human and/or comparative anatomy, and some basic math knowledge (basic calculus and geometry) are beneficial but not mandatory.

Course layout

The course is a lecture-based seminar. Class will start each week with an open discussion of the previous week's readings that you submit (see below) and their application to previously introduced topics. After a break, I (Dr. Auerbach) will follow this discussion with a lecture on the topic of the current week's assigned reading. This is an informal lecture, and your thoughts, questions, and input are welcome at any point during class meetings. After completion of lectures, we will have a discussion of questions that you submit about the current week's course readings (that is, the subject of the lecture). **These questions should be submitted no later than Sunday at 8:00**, and I will post your questions on Blackboard. Each student is expected to submit at least one question each week (except the first week), and other students are encouraged to prepare answers to their peers' questions before class.

As many readings for the course are *not* from peer-reviewed papers, and instead come from edited volumes and textbooks, it is up to you to introduce original research papers to the class. That is, you, as participants, are expected to regularly seek additional publications that are of interest and are relevant to current or past weeks. **You must submit citations of these papers to me no later than Wednesday at 5:00 so that they may be posted on the course web site.** These papers will then be added to the list of readings to be discussed on the subsequent Tuesday. You must provide a paper to the course a minimum of four times during the semester.

So, for each class meeting, you are expected to do the following:

1) You should have read the assigned readings for that week.
2) You should submit at least one question that you have about those readings to me on the Sunday before class.
3) In addition, you should be prepared to discuss the additional peer-reviewed papers added the previous week by your peers and you.

Required texts (Citations for all readings may be found on pages 6 & 7.)

You do not need to purchase any books, though you are *strongly* encouraged to obtain a copy of Vogel's *Comparative Biomechanics* (available at the University Book Store), as well as Currey's *Bones: Structure and Mechanics.* There is a wealth of information in Vogel that we will only touch on in this course. Reading beyond the assigned papers is encouraged. All course readings (including Vogel and Currey) will be provided weekly as PDFs via Blackboard.

Term paper / term project

In addition to weekly participation in course discussions, as well as providing some additional course readings, you are expected to complete a paper based on literature research or an original project. **These will be due on 10 December, one week after the final course meeting**. (However, you are encouraged to submit them at any time prior to this date.) You must choose whether you will complete a literature-based study or conduct and write up a functional anatomy research project. See below for details of each. Also see the "How to Write a Good Term Paper" supplementary document, which may be downloaded on Blackboard.

There are three deadlines to know:

1 – E-mail Dr. Auerbach with your decision to pursue a literature review or original research project no later than 10 September. You will be scheduled to meet with me after this date to discuss the details of your term paper.

2 – Provide an abstract (no more than 400 words) detailing your research to me by 8 October via e-mail.

3 – Term papers are due on 10 December via e-mail to me. **They must be submitted in a MS Word (*.docx) file.**

Literature-based term paper

If you choose to perform a literature-based term paper, it should be an argumentative discussion of a biomechanical topic that is of relevance to biological anthropology, functional anatomy, and/or bone biology. As an argumentative paper, you should establish a position and provide thorough evidence both to support at to argue against that position. Good arguments consider their detractions but are able to provide counter-evidence to those differing opinions.

This term paper option should be no shorter than 15 pages (double-spaced, 12 point font), and should not exceed 25 pages, excluding the bibliography.

Original research project

If you choose to conduct an original research project, you will need to devise a hypothesis that may be tested using the skeletal samples available on campus or other sources of available data. Data that you have previously acquired are eligible, but in order to use them, you should have not utilized them to formally analyze your stated hypothesis. Should you have access to kinematic research equipment (*i.e.* force plates, motion capture, and VO_2 measuring devices), these are also eligible. Be aware that the university IRB and human subjects committees must first approve any research that involves living subjects.

There are extensive skeletal collections available on campus for research. The Small Primate Osteological Collection consists of thousands of pedigreed tamarins, and is curated by me. Likewise, thousands of archaeological modern human skeletons are available via both the Department of Anthropology and the McClung Museum. The Bass Donated Skeletal Collection has hundreds of individuals whose deaths date to the latter 20th and early 21st centuries. I am available to discuss methods for accessing these collections with you.

Your research project should be an original research question, or may be a reanalysis of a published question. In either case, you will need to justify the hypothesis you are testing via a review of salient literature (as you would do in a peer-reviewed paper). It is not expected that the literature review will be as in depth as in the literature-based term paper, but it must be sufficient to support your research goals. Likewise, the data and analyses should sufficiently address the hypothesis, but need not be extensive or more sophisticated than necessary. In short, set realistic goals for a project that may be completed within the confines of a semester. You will always have future opportunities to revisit your research question and expand it as necessary.

Term papers on original research should be no shorter than 15 pages and no longer than 30 pages (double-spaced, 12 point font), which are the general length requirements for many journals' original research papers (*e.g.*, *American Journal of Physical Anthropology*, *Anatomical Record*, *Bone*, etc.). This does not include tables, figures, and the bibliography, all of which should be included separately at the end of the paper, but which should be properly cited in the main text.

Abstract Guidelines

Your abstract should be no more than 400 words. In it, you must establish the problem that your term paper will address. For literature-based papers, you should make your argumentative position in the abstract, which in turn justifies the paper. An example thesis statement would be: "Wolff's Law, as originally defined, does not reflect current knowledge of the processes by which bones maintain their shape in response to mechanical loading." For original research projects, you must state the hypothesis you will be testing. A plan for how you will complete the research (either based on the literature or a research project) must be explicitly discussed as well in the abstract. (In the case of the original research, you should cite the sample you will be using and the methods you will be employing.)

Evaluation

Seminar Questions, Additional Papers, and Class Participation **(40% of the final grade)**

Class attendance, additional paper contributions, submitted seminar questions and active participation in seminar discussions are 40% of the grade for the course. You must submit at least

one question concerning the week's readings on the Sunday prior to the class meeting (except for the first week). Do not forget that you are responsible as well for finding a minimum of four supplementary peer-reviewed papers, which, for a given topic, you will submit no later than the day *after* that topic is discussed in class (*i.e.* each Wednesday).

While I realize that some students do not like to speak in class, given the small enrollment and discussion-based nature of this course, you should make every effort to verbally contribute to course discussions. The more participation you engage in during the class, the more you will get out of the course! I will give feedback throughout the semester concerning your participation, and is available to discuss questions or concerns that you have.

***Term Paper* (60% of the final grade)**

The term paper, as outlined above, along with its abstract, comprises 60% of the grade for the course. Term papers are graded using the point system explained in the "How to Write a Good Term Paper" supplementary document, which may be downloaded from Blackboard. I am available to discuss questions that you have about writing approaches, argumentation, and analytical concerns. While I do not have time to read full drafts of papers prior to their submission, you are welcome to send portions (*i.e.* a section) of your paper to me for feedback before the submission deadline, which is **10 December**. **LATE TERM PAPERS WILL NOT BE ACCEPTED, BARRING EXTREME CIRCUMSTANCES.**

Tips for getting the most out of the course:

As a crucial part of this course is keeping up with the reading before class meetings, you need to give ample time to reflect on the perspectives presented in the chapters and papers you read. On average, you are expected to read between 50 and 100 pages a week in assigned chapters and articles. You are *strongly* encouraged to read broadly, looking into additional sources to help you better develop an understanding of the topics covered. An excellent place to start is always in the references cited within the assigned readings. I am also available to point you toward additional resources as specific questions arise. However, you should use this course as an opportunity to develop skills at independently locating and reading relevant sources to supplement those that are assigned.

Students with special needs:

If you require accommodation because of special needs in learning, please contact the Office of Disability Services at 2227 Dunford Hall (974-6087). Please also contact me immediately via e-mail after you register with the Office of Disability Services. Arrangements will be made to adjust the course to fit your needs.

Books used in the course

DR Carter and GS Beaupré. 2001. *Skeletal function and form: mechanobiology of skeletal development, aging, and regeneration*. Cambridge: Cambridge University Press.

JD Currey. 2002. *Bones: structure and mechanics*. Princeton: Princeton University Press.

RB Martin, DB Burr, and NA Sharkey. 1998. *Skeletal tissue mechanics*. New York: Springer.

C McGowan. 1999. *A practical guide to vertebrate mechanics*. Cambridge: Cambridge University Press.

K Schmidt-Nielsen. 1984. *Scaling: why is animal size so important?* Cambridge: Cambridge University Press.

S Vogel. 2013. *Comparative biomechanics*. Second edition. Princeton: Princeton University Press.

Articles used in the course

Biewener, A.A., 1989a. Scaling Body Support in Mammals: Limb Posture and Muscle Mechanics. Science 245, 45–48.

Biewener, A.A., 1989b. Mammalian terrestrial locomotion and size. BioScience 39, 776–783.

Biewener, A.A., 1993. Safety factors in bone strength. Calcified Tissue Int 53, S68–S74.

Biewener, A.A., Farley, C., Roberts, T., Temaner, M., 2004. Muscle mechanical advantage of human walking and running: implications for energy cost. J Appl Physiol 97, 2266–2274.

Macintosh, A.A., Davies, T.G., Ryan, T.M., Shaw, C.N., Stock, J.T., 2013. Periosteal versus true cross-sectional geometry: a comparison along humeral, femoral, and tibial diaphyses. Am J Phys Anthropol 150, 442–452.

O'Neill, M.C., Ruff, C.B., 2004. Estimating human long bone cross-sectional geometric properties: a comparison of noninvasive methods. J Hum Evol 47, 221–235.

O'Neill, M.C., 2012. Gait-specific metabolic costs and preferred speeds in ring-tailed lemurs (Lemur catta), with implications for the scaling of locomotor costs. Am J Phys Anthropol 149, 356–364.

Organ, J.M., Teaford, M.F., Taylor, A.B., 2009. Functional correlates of fiber architecture of the lateral caudal musculature in prehensile and nonprehensile tails of the platyrrhini (primates) and procyonidae (carnivora). Anat Rec (Hoboken) 292, 827–841.

Polk, J., 2004. Influences of limb proportions and body size on locomotor kinematics in terrestrial primates and fossil hominins. J Hum Evol 47, 237–252.

Pontzer, H., 2005. A new model predicting locomotor cost from limb length via force production. J Exp Biol 208, 1513–1524.

Robling, A.G., Turner, C.H., 2009. Mechanical Signaling for Bone Modeling and Remodeling. Crit Rev Eukar Gene 19, 319–338.

Ruff, C.B., Hayes, W.C., 1983. Cross-sectional geometry of Pecos Pueblo femora and tibiae: a biomechanical investigation. I. Method and general patterns of variation. Am J Phys Anthropol 60, 359–381.

Ruff, C.B., 2000. Body size, body shape, and long bone strength in modern humans. J Hum Evol 38, 269–290.
Ruff, C.B., 2003. Growth in bone strength, body size, and muscle size in a juvenile longitudinal sample. Bone 33, 317–329.
Ruff, C.B., 2006. Gracilization of the modern human skeleton - The latent strength in our slender bones teaches lessons about human lives, current and past. Am Sci 94, 508–514.
Ruff, C.B., 2008. Biomechanical analyses of archaeological human remains. In (Katzenberg MA and Saunders SR, editors): Biological Anthropology of the Human Skeleton. John Wiley & Sons, Inc., New York, pp. 183–206.
Ruff, C., 2009. Relative limb strength and locomotion in Homo habilis. Am J Phys Anthropol 138, 90–100.
Ruff, C.B., Garofalo, E., Holmes, M.A., 2013. Interpreting skeletal growth in the past from a functional and physiological perspective. Am J Phys Anthropol 150, 29–37.
Ruff, C.B., Holt, B., Trinkaus, E., 2006. Who's afraid of the big bad Wolff? 'Wolff is law' and bone functional adaptation. Am J Phys Anthropol 129, 484–498.
Steudel-Numbers, K., Tilkens, M., 2004. The effect of lower limb length on the energetic cost of locomotion: implications for fossil hominins. J Hum Evol 47, 95–109.
Stock, J.T., Shaw, C.N., 2007. Which measures of diaphyseal robusticity are robust? A comparison of external methods of quantifying the strength of long bone diaphyses to cross-sectional geometric properties. Am J Phys Anthropol 134, 412–423.
Sylvester, A.D., Mahfouz, M.R., Kramer, P.A., 2011. The Effective Mechanical Advantage of A.L. 129-1a for Knee Extension. Anat Rec 294, 1486–1499.

COURSE SCHEDULE – Fall 2013: Biomechanics (ANTH 595)

DATE	TOPIC	READING	NOTES
27 AUG	Introduction to biomechanics	Vogel: Chapter 1 Ruff (2006) Ruff (2008)	*No seminar questions this week*
3 SEPT	Bone, part one: Bone biology	Currey: Chapter 1 Martin *et al.*: Chapter 2 Ruff et al. (2006)	Additional reference: Robling & Turner (2009)
10 SEPT	Material mechanics	Currey: Chapter 2 Vogel: Chapters 2, 3 & 15	*Decide which term paper type you are writing*
17 SEPT	Bone, part two: Basic bone mechanics	Currey: Chapter 3 McGowan: Chapters 4 & 5	Additional reference: Martin et al.: Chapter 4
24 SEPT	Bone, part three: beam theory	Vogel: Chapter 19 McGowan: Chapters 6 & 7	
1 OCT	Scaling	Schmidt-Neilsen: Chapters 1-5, 17 Biewener (1989a, 1989b) Vogel: Appendix 3	
8 OCT	Cross-sectional properties of bone	Currey: Chapter 4 Ruff and Hayes (1983) Ruff (2000) (Also reference Vogel: Chapter 19)	*Term paper abstracts due*
15 OCT	Practicum: How to calculate bone mechanical properties	O'Neill and Ruff (2004) Stock and Shaw (2007) Macintosh *et al.* (2013)	
22 OCT	Ontogeny and bone mechanics	Ruff et al. (2013) Carter and Beaupré: Chapters 3, 4 & 5	Additional reference: Ruff (2003)
29 OCT	Joint mechanics	Vogel: Chapter 20 McGowan: Chapter 8 Currey: Chapter 8	

DATE	TOPIC	READING	NOTES
5 NOV	The basics of muscle mechanics	McGowan: Chapter 9 Vogel: Chapter 23	Additional reference: Organ et al. (2009)
12 NOV	Moving, mobility, and muscle	Vogel: Chapters 24 & 25 McGowan: Chapter 10	
19 NOV	Safety factors and effective mechanical advantage	Biewener (1993) Currey: Chapter 10 Polk et al. (2004)	Additional reference: Sylvester et al. (2011)
26 NOV	Cost of transport and kinematics	O'Neill (2012) Biewener *et al.* (2004) Steudel-Numbers & Tilkens (2004)	Additional reference: Pontzer (2005)
3 DEC	Evolution and mechanobiology	Carter and Beaupré: Chapters 1 & 9 Ruff (2009)	
10 DEC	**TERM PAPERS DUE BY 8:00 P.M.**		