COTLOW FIELD RESEARCH FUND

Department of Anthropology
The George Washington University
Washington, DC 20052

Project Description Form

Applicant:

Nicole L. Griffin

Title of Project:

Hominid Forefoot Kinematics, Kinetics, and Bone Architecture

The Lewis Cotlow Field Research Fund is a GW Anthropology Department fund, established in 1990 as a bequest by the explorer Lewis B. Cotlow to further field work and exploration. All undergraduate or graduate students at The George Washington University are eligible to apply, but preference is given to those in anthropology programs. Funds are to be used for travel, research assistance, and other expenses related to field research.

The deadline for application is the first Friday in March of the year for which support is requested.

DESCRIPTION OF PROPOSED COTLOW FIELD RESEARCH PROJECT

I. Personal Information

Name: **Nicole L. Griffin**

Permanent Address:

Current Address:

Home Phone: Work Phone:

E-mail Address(es):

Degree Sought: **PhD** Field of Study: **Hominid Paleobiology**

Expected Date of Graduation: **May 2008**

Faculty Advisor for This Project: **Dr. Brian G. Richmond**

Does your proposed project involve the use of a "field language"? **No**

II. Brief Abstract of the Project

Title of Project: Hominid Forefoot Kinematics, Kinetics, and Bone Architecture

Amount Requested: $1,500.00

Abstract: Paleoanthropologists disagree about whether early human ancestors were habitual, upright bipeds as modern humans are or if the former also incorporated climbing into their daily regime. This study will quantify the three-dimensional spongy bone structure and measure toe joint angles and plantar pressures of living great apes in order to form a basis for resolving current debates about early hominin locomotion. The overarching goal of this research is to improve our understanding of the evolution of bipedalism in human lineage.

III. Significance of the Project. What is the relationship of the proposed research to other anthropological research in this field and region? (200-500 words)

Habitual bipedalism - walking exclusively on two legs - is a form of gait practiced by humans to the exclusion of all other living primates, even our closest relatives, the African and Asian apes. Scientists have often have relied on hard tissue characteristics of the skeleton that distinguish humans from other living great apes (hominids) to infer locomotor regimes (gait) of fossil taxa. When fossil foot bones are recovered, researchers usually compare traits in a qualitative fashion and/or use external metrics. Though these methods are useful in capturing size and shape similarities and differences, they can prove unsatisfactory in circumstances when the development and/or function of a trait are not well known or when studies employing similar methodologies have conflicting results. In these cases, the utility of a particular trait is questionable. For example, researchers disagree over whether or not early hominins (3-4 mya, or million years ago) used a 'toe-off' mechanism that we use when we walk. The disagreement stems from the inability of the external structure of the toe joints, notably the metatarsopha-langeal joints (MTPJ, between the toes and other foot bones), to distinguish foot biomechanics among primates. While some paleoanthropologists have found evidence that hominins living as far back as 4 mya share with living humans a characteristically similar MTPJ complex (i.e. dorsal expansion of the distal articular surface of the metatarsal and dorsal canting of the proximal articular surface of the proximal pedal phalanx), one that is designed for the toe-off phase of the bipedal gait cycle (Latimer and Lovejoy 1990), a subsequent investigation using similar methodologies did not achieve the same results (Duncan et al. 1994). Duncan et al. (1994) found that it was not possible to quantitatively differentiate the MTPJ morphology of humans and great apes and presented the caveat that this type of analysis is not useful for making

inferences about the locomotor behavior of fossils. The authors of this study suggest that future research considering the three-dimensional structure in this region of the forefoot is necessary to determine if first, humans and great apes exhibit different morphologies and second, if these differences can be used as evidence to infer positional behaviors of fossil taxa.

Understanding the range of forefoot form and function among living hominids is essential for interpreting fossil foot remains of our ancestors. This proposal requests support to develop and test novel and more direct research methods for quantifying the functional anatomy of the higher primate forefoot in order to reconcile contrasting results and interpretations left by previous studies. This research will test the relationships among extant hominid metatarsophalangeal posture, loading, and internal bone architecture to determine if a reliable form and function relationship can be inferred. Specifically, **this study will collect and compare living hominid metatarsophalangeal joint kinematic, kinetic, and bone architectural data.** The results will form a baseline for inferring positional behavior of fossil hominins from forefoot trabecular morphology. Since trabecular bone reflects use during life, this approach has the potential to resolve current debates surrounding early hominin foot function.

IV. Methodology. What are the specific research questions you plan to ask? What data will you generate and how? How do you plan to use these data to address and resolve your research questions? *Be specific.* Attach an additional page if necessary. (200-500 words)

MTPJ trabecular bone architecture will be studied in hominids (*Homo sapiens*, *Pongo pygmaeus*, *Gorilla gorilla*, *Pan paniscus* and *Pan troglodytes*) to determine if (a) trabecular bone volume, (b) anatomical orientation, and (c) degree of anisotropy (strength of orientation in a particular direction or directions) can discriminate among positional behaviors. It is expected that humans will show the greatest degree of anisotropy at the 1st, 2nd, and 3rd MTPJs because they are habitual bipeds and exhibit a more consistent pattern of foot posture and leverage during gait (Vereecke et al. 2003). In addition, it is hypothesized that comparisons of human metatarsal (MT) and proximal phalangeal (PP) trabeculae will show an increase in relative bone volume and degree of anisotropy from plantar to dorsal regions because most compression occurs in the dorsal area of the joint during close-packed dorsiflexion (Hetherington et al. 1989). Trabecular bone analysis will be completed using the Quant3D program.

Forefoot angles and plantar pressures will be quantified to determine and compare the typical ranges of sagittal motion and loading in chimpanzees (*Pan paniscus* and *Pan troglodytes*) and human metatarsophalangeal joints (MTPJs). Data will not be collected for *Gorilla* or *Pongo* now, due to logistical and time constraints. It is predicted that humans will exhibit significantly greater degrees of MTPJ dorsiflexion and loading prior to the push-off phase during barefoot running and walking than quadrupedal, climbing, or bipedal chimpanzees. In addition, it is also expected that human MTPJs dorsiflexion will increase with speed.

Funding is requested for travel and living expenses during a two-month stay in Belgium to collaborate with Dr. Kristiaan D'Août of the University of Antwerp and collect human and *Pan in vivo* data. Dr. D'Août and colleagues have conducted several well-known kinematic

investigations at both facilities, thus equipment and non-human primate and human subjects will be readily available for my project (D'Aout et al. 2002; D'Aout et al. 2004; Vereecke et al. 2006). We will recruit 10 male and 10 healthy female, adult human volunteers within a similar body mass and age range from the University of Antwerp. Kinematics and kinetics of adult *Pan paniscus* (n = 6) and *Pan troglodytes* (n = 10) will be measured at both the Animal Park Planckendael and the Antwerp Zoo, respectively. The same runway, camera setup, and pressure mat for the human trials will be used for the chimpanzee trials. MTPJ angles will be collected in 3D, following the protocol of Vereecke et al. (2006). Data will be analyzed using Peak Motus Software.

Before comparisons can be made between *Pan* and human *in vivo* data, variation within each taxon needs to be explored. Multiple regressions will be run to test for relationships between biomechanical variables and age, speed, and body mass. Also, plantar pressures will be standardized by dividing values by body weight. Mann-Whitney U and Kruskall-Wallis tests will be conducted to determine taxonomic differences for *in vivo* MTPJ angles, plantar pressures, and trabecular bone properties.

V. Ethics (150-200 words)

This project will adhere to The George Washington's IACUC and IRB guidelines and the Royal Zoological Society of Antwerp's (Koninklijke Maatschappij voor Dierkunde van Antwerpen vzw) standards for animal treatment. Permissions and documents of approval are attached.

VI. Product. What kinds of results do you expect to come from the proposed research? (E.g., publishable article, presentation at a professional meeting, film, museum exhibit, etc.)

The results of this project will be included in my dissertation and in manuscripts I will submit for publication.

VII. Schedule. State clearly your timetable of specific research activities.

May-July 2007:

- 6 weeks of video and plantar pressure data collection of chimpanzee and human subjects in Belgium with Dr. Kristiaan D'Août.

Fall 2007:

- Data analysis and manuscript preparation.

VIII. Budget. Provide a detailed budget for the proposed activities. Among the expenses you may need to include are transportation, room and board, and research supplies; the Cotlow Fund can not be used to pay tuition or academic fees. *Past awards have typically been about $1500.*

An amount of $1,500.00 will help defray a round-trip plane ticket to Brussels ($979.00, www.travelzoo.com) and costs of living [$2010.00 ($33.50 per day *60 days, estimated with the assistance of local resident, Dr. D'Août)].

IX. Staff. If others are to participate in the project as investigators or assistants, please give their names and qualifications.

Dr. Kristiaan D'Août, University of Antwerp (CDE), Department of Biology, Laboratory for Functional Morphology.

X. Outside Support. List any other sources of funding for the project, with amounts and restrictions (if any).

Pending.

XI. Select bibliography.

D'Aout, K., P. Aerts, D. De Clercq, K. De Meester and L. Van Elsacker (2002). "Segment and joint angles of hind limb during bipedal and quadrupedal walking of the bonobo (Pan paniscus)." Am J Phys Anthropol **119**(1): 37-51.

D'Aout, K., E. Vereecke, K. Schoonaert, D. De Clercq, L. Van Elsacker and P. Aerts (2004). "Locomotion in bonobos (Pan paniscus): differences and similarities between bipedal and quadrupedal terrestrial walking, and a comparison with other locomotor modes." J Anat **204**(5): 353-61.

Duncan, A., J. Kappelman and L. Shapiro (1994). "Metatarsophalangeal joint function and positional behavior in *Australopithecus afarensis*." Amer. J. Phys. Anthrop. **93**: 67-81.

Hetherington, V. J., J. Carnett and B. A. Patterson (1989). "Motion of the first metatarsophalangeal joint." J Foot Surg **28**(1): 13-9.

Latimer, B. and C. Lovejoy (1990). "Metatarsophalangeal joints of *Australopithecus afarensis*." Amer. J. Phys. Anthrop. **83**: 13-23.

Vereecke, E., K. D'Aout, D. De Clercq, L. Van Elsacker and P. Aerts (2003). "Dynamic plantar pressure distribution during terrestrial locomotion of bonobos (Pan paniscus)." Am J Phys Anthropol **120**(4): 373-83.

Vereecke, E. E., K. D'Aout and P. Aerts (2006). "Speed modulation in hylobatid bipedalism: a kinematic analysis." J Hum Evol **51**(5): 513-26.

XII. Transcript. Please submit a copy of your academic transcript (official or unofficial) with this form.

Attached.

XIII. Permits. Various permits may be necessary to conduct the proposed research (e.g., research visas, research permits, antiquities permits, Historical Preservation Committee approvals, health forms, research on human subjects forms). If you will be doing ethnographic or linguistic research, you may have to obtain proper consent from your informants; contact GW' s Office of Sponsored Research to determine if Research on Human Subjects permission is necessary (call 994-6255, 6th floor Rice Hall). If no such permission is necessary, state that below. If you have the requisite paperwork, attach copies; if you do not yet have it, summarize the steps you have taken to obtain it.

Not applicable.