This is provided as an example proposal. It is important that you follow the current guidelines.

The mentor letter has been removed.

PURF COVER PAGE

TITLE OF PROJECT: Hind limb anatomy in Ceratosauria: Insight from an exquisitely preserved foot of Majungasaurus

NAME OF APPLICANT: Alexander Acker
E-MAIL ADDRESS: aa545118@ohio.edu
DEPARTMENT: Biological Sciences
BUDGET: Total Request $1500

$1,500
(May not exceed $1,500)

CLASS RANK: ◯ Freshman ◯ Sophomore ◯ Junior ◉ Senior
GPA: 3.517
EXPECTED DATE OF GRADUATION: 05/05/2023 *

* Note: Students must be enrolled and maintain undergraduate student status during the proposed project period.

FACULTY MENTOR INFORMATION:
NAME: Patrick OConnor
E-MAIL ADDRESS: oconnorp@ohio.edu
DEPARTMENT: Biomedical Sciences
DEPARTMENT ADMIN: NAME & EMAIL Jamie Remy
remyj@ohio.edu

We the undersigned have read the PURF Guidelines and understand the responsibilities we undertake should funding be granted.
We certify that the application has been conceived, written and completed by the student.

Student signature: Alexander Acker Date: 9/29/2022
Faculty signature: Date: 09/29/2022
Faculty Advisor's Dept. Chair signature: Erin Murphy Date: 09/29/2022

IRB AND IACUC APPROVAL:
To ensure that the University's compliance with all federal regulations, complete the checklist below.
Note: if your IRB/IACUC is not approved prior to submission put "pending" or "to be submitted" instead of approval number. Note: but funding will be withheld until notification of approval or exemption.

Yes	*No*	*Office of Research Compliance*	*Policy #*
☐	☑	Human Subjects in Research: Institutional Review Board (IRB) Approval #: Expiration Date:	19.052
☐	☑	Animal Species: Institutional Animal Care & Use Committee (IACUC) Approval #: Expiration Date:	19.049

☑ **Optional:**
If selected for funding, I give permission to the Research Division to use my proposal as an example during training and workshop exercises. (Sign below)
Signature: Alexander Acker Date: 09/29/2022

1. ABSTRACT

Ceratosauria was one of the most successful groups of non-avian dinosaurs. They lived in many habitats across the globe. Despite this, their hind limb anatomy has been sparsely studied due in part to an incomplete fossil record and a disregard from scientists. My project will mitigate this by describing exquisitely preserved fossils of *Majungasaurus*, along with detailed comparisons of other species in the group. I will use anatomical description, high-resolution photography, and measurements of fossils to develop a comprehensive record of variation in foot morphology. These data will provide essential context for higher-level studies of locomotor evolution in the group.

2. PROJECT NARRATIVE

Goals and Scope

Locomotion is one of the most important aspects of animal biology, as it allows species to traverse their environment. Without locomotion, animals wouldn't be able to meet their basic needs such as finding food, water, and conspecifics. Research on the limb skeleton of dinosaurs has provided insight into everything from the origin of flight in birds to understanding the biomechanical implications for the heaviest land animals to have ever existed. Whereas locomotor biology is extensively studied in living groups of animals, it is rarely examined in extinct animals outside of basic biomechanical modeling. There are numerous studies that deliver detailed descriptions of cranial anatomy on new specimens, but provide only generalized statements on other parts of the skeleton. I'd like to change this trend by using two focal species of non-avian theropod dinosaurs, *Majungasaurus* and *Ceratosaurus*. This will provide new perspectives on the locomotor biology within Ceratosauria, the most diverse group of early-branching non-avian theropod dinosaurs. In the lab, we are currently studying the most complete foot of *Majungasaurus* found to date, representing the first phase of my research project. Visiting the museum collections as part of this PURF proposal will allow me to place the new specimens of *Majungasaurus* into a broader comparative perspective and is essential for providing new data on ceratosaurian locomotor biology.

Context

Descriptions of hind limb anatomy and related biomechanical studies of locomotor potential have received mixed attention in non-avian theropod dinosaurs. Fortunately, there are two groups of non-avian theropods that have had their hind limbs studied extensively. These include

tyrannosaurids and dromaeosaurids (e.g., *Velociraptor*). For example, Brochu (2003) provides a detailed description of the foot of *Tyrannosaurus rex*, with several higher-level studies (e.g., Hutchinson et al., 2011) using this information to consider locomotor potential in this species. Despite that neither tyrannosaurs nor dromaeosaurs are in my study group (i.e., Ceratosauria), comparisons of basic foot anatomy still ring true and assist in providing comparative perspectives essential for my work. Carrano (2007) includes a great description of the best foot of any dinosaur within Ceratosauria. Although an incomplete skeleton was described, this paper was essential for my understanding foot anatomy of *Majungasaurus*. Cerroni (2022) is a more recent example of exemplary hind limb description. This study has been useful for understanding new parts of the foot preserved in my specimen. Work by Welles (2000) has been important for me to grasp the basic anatomical details of *Ceratosaurus*. However, unlike previous studies, my project will examine two important species within Ceratosauria, including a new, near-complete foot and hind limb of *Majungasaurus*, providing important perspectives on the major group of early diverging non-avian dinosaurs. My anatomical description of these new materials, along with my comparative study of *Ceratosaurus*, is a necessary first step before considering the evolution of the locomotor apparatus more generally in the group.

Methods

To compare the anatomy of these fossils, I will be taking high-resolution digital photographs and measurements of each specimen. I will use digital calipers to collect the basic dimensions (e.g., length, diameter, etc.) of each bone as well as measurements of specific features of interest (e.g., length from muscle attachment points to the end of the bone). Size data will be used for two specific purposes. First, these types of data are crucial for characterizing intraspecific variation

within a single species and for discerning differences among different species. Second, detailed size data are necessary for generating biomechanical models that are crucial for constraining foot and hind limb anatomy in different locomotor positions (e.g., during touchdown and stance phases). Photographs will be taken to visually highlight these characteristics. In addition to this, digital photographs and 3D models will be useful while in the collections because I will be able to use these for direct comparisons with the bones in front of me. Digital models of *Majungasaurus* will also be permanently housed in the online digital repository Morphosource (www.morphosource.org), allowing others to use these data for research, education, and exhibition purposes.

Timeline

The groundwork for this research has already been laid as I have been studying specimens of *Majungasaurus* since April 2022, when our lab received recently prepared specimens (*of just the feet*) from the Denver Museum of Nature & Science. I am completing a research poster for that project and will be presenting it at an international conference in Toronto, Ontario in November 2022. The study of specimens in both Denver and Washington DC as proposed here will allow me to examine additional specimens of *Majungasaurus* and the holotype specimen (Gilmore, 1920) of *Ceratosaurus*. I am planning to visit DMNS in January 2023 and NMNH in February 2023, allowing me time to incorporate this information into an abstract for the 2023 Society of Vertebrate Paleontology meeting. Abstracts for this conference will be due in April 2023. These new data will also be presented at the OHIO Student Expo to be held in spring 2023.

Student's role

During this project, I will be learning how to conduct anatomical research under the supervision of Dr. Patrick O'Connor. We developed the research idea together as we wanted to identify a project that fits within my research interests while also being a good foray into paleontological research for an undergraduate student. Dr. O'Connor has already introduced me to basic anatomical visualization through work in his laboratory. This project will provide the next sequence of training on how to quantify morphology and use it for comparative (phylogenetic) analyses. My specific role will be to collect the data necessary for these analyses. After collecting data in the museum, I will compile digital photographs into an atlas and link quantitative specimen data to images in the atlas. Dr. O'Connor and I will then work to integrate these new details into an ongoing phylogenetic analysis of ceratosaurian theropods. Finally, Dr. O'Connor and his colleagues are currently preparing additional specimens from the same *Majungasaurus* skeleton from which the feet I've studied belong. Any insights that I'm able to find will be very useful to that project.

Significance

Ceratosauridae is one of the best-known clades of early diverging non-avian theropod dinosaurs. This group represents animals from across the globe, from across a significant portion of the Mesozoic Era, and importantly, from many different environments and inferred ecological niches. Better understanding the anatomy of the foot and hind limb will allow us to develop and address more intricate questions related to biomechanics and phylogenetics. However, a solid anatomical foundation must first be established to conduct these more elaborate studies. Findings from this study may also prove useful to ornithologists and other scientists interested in the evolution of complex trait systems. Given that ceratosaurians are one of the earliest diverging groups of non-avian theropods, examining how traits of the hind limb and feet (specifically)

evolved in this group is critical for a broader understanding of the anatomical systems responsible for that divergence.

4. BIBLIOGRAPHY

Brochu, C. A. (2003). Osteology of *Tyrannosaurus rex*: Insights from a Nearly Complete Skeleton and High-Resolution Computed Tomographic Analysis of the Skull. Journal of Vertebrate Paleontology - J VERTEBRATE PALEONTOL. 22. 1-138. 10.1080/02724634.2003.10010947.

Carrano, M. T. (2007). The appendicular skeleton of Majungasaurus crenatissimus (Theropoda: Abelisauridae) from the Late Cretaceous of Madagascar. Journal of Vertebrate Paleontology. 27. 163-179. 10.1671/0272-4634(2007)27[163:TASOMC]2.0.CO;2.

Cerroni, Mauricio & Baiano, Mattia & Canale, Juan & Agnolin, Federico & Otero, Alejandro & Novas, Fernando. (2022). Appendicular osteology of Skorpiovenator bustingorryi (Theropoda, Abelisauridae) with comments on phylogenetic features of abelisaurids. Journal of Systematic Palaeontology. 20. 10.1080/14772019.2022.2093661.

Hutchinson, J. & Bates, K. Molnar, J. Allen, V. & Makovicky, P. (2011). A Computational Analysis of Limb and Body Dimensions in *Tyrannosaurus rex* with Implications for Locomotion, Ontogeny, and Growth. PLoS ONE. 6. e26037. 10.1371/journal.pone.0026037.

Madsen, J. H., and Welles, S.P.. (2000). *Ceratosaurus* (Dinosauria, Theropoda) a revised osteology.

5. BIOGRAPHICAL INFORMATION

Over the past three years, I have gained valuable research experience in Dr. O'Connor's lab. I've been fortunate to learn many new skills, particularly given that the COVID pandemic caused me to lose in-person access to the laboratory for the final part of my freshman year and the entire span of my sophomore year. Thanks to remote access to the O'Connor lab computers, I have still learned many important skills for this project, including using Avizo to segment and create 3-D models of fossils, understanding the anatomy of dinosaurs, explaining science to the general public, and many other useful paleontological approaches. Concurrently, I've been taking classes such as comparative vertebrate anatomy and principles of paleontology. These courses reinforced and expanded upon ideas in science that I needed to conduct my research. I've also had the opportunity to join Dr. Zanno and her team at the North Carolina Museum of Natural Sciences for fieldwork in Utah. While my current research endeavors don't have a fieldwork component, understanding how the process of fossilization can change a fossil, and knowing the proper handling techniques of fossils will be important while in collections.

6. BUDGET

a. Itemized budget for travel:

Travel to Denver Museum of Nature & Science for four days of research in the collection

Airfare estimate: $153 for round trip flight

Hotel estimate: $492 for a 6-day stay at Super 8

Food estimate: $120 for 6 days of food

Ground Transportation: $30 Uber

Travel to the Smithsonian (National Museum of Natural History) for two days of research in the collection.

Airfare estimate: $180 for roundtrip flight

Hotel estimate: $ $460 for 4 days at Days Inn

Food estimate: $90 for 4 days of food

Ground Transportation: $30 Uber

Total : $ 1, 555

I will be able to cover the extra $55 on my own.

b. Non-travel expenses:

The in-laboratory expenses (shipping fossils, uCT scanning, computer access) for this projve have been provided by Dr. O'Connor.

DENVER MUSEUM OF NATURE & SCIENCE

September 27, 2022

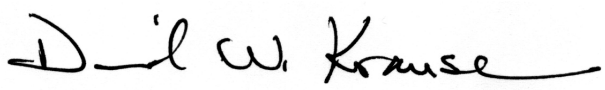
Mr. Alex Acker
Ohio Center for Ecological and Evolutionary Studies
Department of Biomedical Sciences
119 Life Sciences Building
Heritage College of Osteopathic Medicine
Ohio University
Athens, OH 45701

Dear Alex —

I am writing in strong and enthusiastic support of your request to examine hind limb specimens of the theropod dinosaur *Majungasaurus crenatissimus* from the Late Cretaceous of Madagascar housed here at the Denver Museum of Nature & Science. We will make the specimens available to you and provide access to bench space and, if you need it, a microscope. Please let us know when you expect to conduct this research and if you anticipate any other needs.

If you have any questions, please do not hesitate to contact me (telephone: 631-942-7232; e-mail: David.Krause@dmns.org).

Sincerely,



David W. Krause
Senior Curator of Vertebrate Paleontology
Department of Earth Sciences
Denver Museum of Nature & Science

Distinguished Service Professor Emeritus
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Smithsonian
National Museum of Natural History

Department of Paleobiology

September 29, 2022

Mr. Alex Acker
Ohio Center for Ecological and Evolutionary Studies
Department of Biomedical Sciences
119 Life Sciences Building
Heritage College of Osteopathic Medicine
Ohio University
Athens, OH 45701

Dear Mr. Acker,

I am writing to confirm that you are welcome to visit the Department of Paleobiology at the Smithsonian Institution and study theropod dinosaur materials in our vertebrate fossil collections. We have materials of *Ceratosaurus* and *Allosaurus* that may be well-suited to your research needs., can provide a workspace and access to a microscope and photography stand, as needed. Note that exhibition materials require morning-only access.

When you are ready to plan your visit, please visit our webpage (https://naturalhistory.si.edu/research/paleobiology/collections-access) to create a formal "visit request," but you should feel free to contact me directly as well for advice and guidance (carranom@si.edu).

Sincerely,

Matthew Carrano
Curator of Dinosauria

SMITHSONIAN INSTITUTION
NHB E-105, MRC 121
10th and Constitution Avenues NW
Washington, DC 20560-0121
202.633.1314 Telephone
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