SOAR Research Proposal
Summer 2018

Kinematics of prey handling in arboreal snakes

Faculty Mentor: Dr. Frances Irish, Associate Professor of Biological Sciences

Students: Emma Adam and Tevo'n Campbell

Project start date and duration: June 4 - Aug 10, 2018 (10 weeks)

Background for the project: Snakes are renowned for their ability to swallow large prey whole. They are able to do this because they have highly kinetic skulls with many moving parts. The snout and upper jaws are movably attached to the braincase by ligaments, allowing snakes to move the jaws on each side of the head independently. When swallowing, snakes anchor the prey with the jaws on one side of the head while advancing the jaws on the other side, thus "walking" the head over the prey using unilateral movements. Because the snout is loosely tied to the upper jaws by connective tissues, the snout passively tracks the upper jaws as they move.

Elevation of the snout around its attachment to the braincase (the nasofrontal joint) is not uncommon in vertebrates such as lizards and birds, though it is unknown in mammals. But snout twisting (rotation around a longitudinal axis) is a little-studied ability found only in snakes, where it appears to be an integral part of the unique snake unilateral swallowing mechanism described above.

Previous SOAR projects focused on burrowing snakes (sand boas in the genus *Eryx*) to test the hypothesis that enlargement of the nasofrontal joint to resist the stresses of burrowing should restrict snout movement. We found that snout elevation in sand boas is comparable to the scant published records for non-burrowing snakes, but snout twisting is very limited. Restricted snout movement could be an adaptation for burrowing, or simply the retention of an ancestral feature. To answer this question, we sought data on a broader array of boa species, especially non-burrowing taxa. Unfortunately, interpretation of the results depends on how the species are related to each other, and recent phylogenetic studies do not agree. But notably, we also found surprisingly wide variation in snout twisting ability between species, even among closely related species of similar diet and ecology---from 8^{o} in rainbow boas to 65^{o} in boa constrictors, both large terrestrial snakes that eat small mammals. Why?

Description of proposed summer 2018 SOAR project:

To gain perspective on the larger issue of what might drive the evolution of extreme snout mobility, we decided to turn to snakes with very different habits---namely, arboreal species that spend much of their lives off the ground. The students will work together to record feeding in Asian vine snakes (*Ahaetulla prasina*), juvenile Hispaniolan boas (*Chilabothrus striatus*), and Solomon Island tree boas (*Candoia bibroni*). The students will:

1. Read relevant literature on snake feeding mechanics.
2. Record strikes to live prey on high-speed video (500 frames per second).

3. Record prey manipulation and swallowing at "normal" speed (60 frames per second) with a high-definition video camera.
4. Do frame-by-frame analysis of video records, measuring the angles of rotation of snout and upper jaws using "Tracker" software.
5. Examine the connections between the braincase, snout, and upper jaws in dried skulls and relevant preserved specimens in order to understand how the observed movements are accomplished.
6. Place the data in an evolutionary context by comparing chosen arboreal species with previously collected student data on burrowing sand boas, non-burrowing boas, and more distantly related non-burrowing colubrids.
7. Synthesize results for presentation.

Two students are needed for this project because it is nearly impossible for one person to keep the camera focused on a moving target and introduce live prey into the filming arena at the same time. I can (and have) adopted the role of assistant, but I believe the research experience will be more valuable if the students come to "own" the project by being allowed some level of autonomy---i.e. being able to conduct recording sessions by themselves. During previous SOAR projects the synergy between the students was extremely fruitful. The students will work together when recording data, but each will focus on a different snake species during data analysis.

Experimental animals: The snake species needed for this project are currently housed in the animal facility at Moravian College. The students will help maintain experimental animals and their prey (mice) during the course of the study. Protocols for the SOAR-funded previous phases of this project were approved by the IACUC committee at Moravian College, and approval will be sought for summer 2018 as well.

Roles and responsibilities of faculty and students:
Faculty role & responsibilities: I have been filming snakes feeding for the past 15 years, and have studied snake anatomy extensively through gross dissection, histological study, and skeletal preparation, and I am a co-author on two book chapters on the snake skull and prey capture kinematics. I will mentor the students on a daily basis, guiding them in their search for background literature, instructing them in experimental techniques and use of specialized equipment, assisting in data collection, data analysis, and appropriate care of animals, and helping them prepare their results for presentation.

Student role and responsibilities: The proposed project is part of an on-going research program, but Emma and Tevo'n will participate in all aspects of the work, from animal maintenance to experimental design, data gathering, data analysis, and presentation, as outlined above.

Project timetable:

Week 1: Instruct students in animal maintenance chores; supervise literature search; familiarize students with snake head anatomy; record preliminary data to gain experience using the camera equipment.

Weeks 2-8: Make digital video recordings of snakes capturing and swallowing prey; analyze resulting data on snout and upper jaw movements each day; relate observed kinematics to head anatomy.

Weeks 9-10: Finish data analysis, synthesize experimental and anatomical data for presentation, draft poster.

Student engagement in scholarly research and contributions to the discipline:

Emma is currently planning to go to veterinary school, so familiarity with the techniques of experimental morphology should have particular relevance for her. Tevo'n plans to pursue graduate studies in Forensic Science, where the ability to analyze and solve unexpected problems (which often arise when working with live animals) should be a useful skill. Emma and Tevo'n both took General Zoology (Biology 112) from me, so they have had important background material that should help them understand the context of this study. This project will require them to elucidate the anatomy without the aid of a dissection manual, as the anatomy of these snakes is, in many cases, poorly known. Hands-on research experience and formal presentation of the results should make Emma and Tevo'n more competitive in applying to postgraduate studies, and better prepared to succeed. They will present their work for scholar's day at Moravian College, as required of SOAR students, and for an audience of peers beyond Moravian College, such as the National Conference on Undergraduate Research and/or the Lehigh Valley Evolution and Ecology Symposium, where past SOAR students have presented their work.

This project stems from observations made during a long-term study of prey capture behavior in boas and pythons that I have been pursuing in collaboration with Dr. David Cundall of Lehigh University. Early data have been published, but given the fact that these animals are ectothermic and are adapted to going without food for long periods of time, amassing a large data set takes time, patience, and ingenuity. A critical part of my job is mentoring undergraduates in a research setting. The project outlined here is publishable material; data collected this summer will be vital to finishing the experimental aspects of the research so results can be submitted for publication in a peer-reviewed journal.

In today's world, where we enjoy many of the benefits of scientific discovery, it is vital that our students understand the nature of science and the process by which scientific discoveries are made. Having our undergraduates actively engaged in scientific discovery brings hands-on science into the community of undergraduate scholars at the college. Formal presentation and eventual publication of student-faculty collaborative research enhances the reputation of Moravian College, and is a selling point for prospective students.

Expense proposal

Project title: ***Kinematics of prey handling in arboreal snakes***

Faculty mentor: Dr. Frances Irish

Students: Emma Adam and Tevo'n Campbell

$ 300	Expendable supplies. Includes dissection materials, animal food & bedding, additional research animals (if required), etc. The primary research equipment for this project (cameras, lights, filming box, computer software, etc.) is available in-house. The Department of Biological Sciences will supply additional equipment and supplies if required.
$ 300	Total

Student Statement of Purpose
Summer 2018

Project Title: ***Kinematics of prey handling in arboreal snakes***
Student: Emma Adam
Major: Chemistry (Pre-Vet track)
Expected year of graduation: 2019
Faculty mentor: Dr. Frances Irish
On-Campus housing: Requested

I have been interested in veterinary medicine since I was six years of age. As I grew older, the desire to help animals slowly formed into a desire to study them as well. Animal studies have always been my passion, and I am currently trying to expand my knowledge on exotic species of animals. My passion for animals has led me to the opportunity to perform research in a field that I hope to have a career in as well as perform research on exotic animals to gain more knowledge of their living habits and eating techniques.

I approached Dr. Irish about participating in the SOAR program with a project revolving around snakes in particular. This project specifically deals with arboreal snakes, such as Asian vine snakes (*Ahaetulla prasina*), juvenile Hispaniolan boas (*Chilabothrus striatus*), and Solomon Island tree boas (*Candoia bibroni*). By studying these snakes, I will gain knowledge of their living environments, how to care for them, and the snout and upper jaw movements when feeding. I will also research if these results are similar to or different from other species of snakes. This will be important research in the biology and exotic veterinary community, helping scientists and veterinarians to better understand these interesting animals. As a student who wants to have a career in a small animal and small exotic veterinary practice, this project will provide crucial information on these snake species that could be used for future experiments and research.

From this incredible opportunity to engage with species of snakes that are not as well known, I will gain valuable insight into arboreal snake behavior and the small exotic animal discipline. From a veterinary point of view, I will have the opportunity to care for these snakes. This includes feeding, devising a suitable enclosure, and overall care of the snakes, as well as learning about the snakes' behavior. I will also learn more about how these species of snakes twist their snouts when they eat. This will provide me with skills to analyze live animals as well as gain experience working with live animals, skills that are difficult to develop in the 3-hour labs at Moravian College. This project will give me insight into the exotic veterinary and biology field, helping me prepare for my future postgraduate studies. Working closely with Dr. Irish, I will get firsthand experience on the methodology and techniques experienced scientists use in live animal and biology research, giving me practical and beneficial experience in the laboratory and helping to develop my skills as an independent scientist. Also, committing my time to a single project will allow me to submerge myself in my research and develop the ability to trouble shoot and experiment with these snakes. I will carry this useful experience over into my graduate studies at veterinary school, where I will continue my journey to study small animals and small exotics.

Student Statement of Purpose
Summer 2018

Project Title: ***Kinematics of prey handling in arboreal snakes***
Student: Tevo'n Campbell
Major: Undeclared
Expected date of graduation: May 2021
Faculty Mentor: Dr. Frances Irish
On-campus housing: requested

The SOAR program is an excellent opportunity for any student to gain experience doing original research. Even though I am basically an infant in terms of my college career, I foresee that this research program could open many doors in the future by elevating the status of any application, not only to graduate school, but also to prospective jobs. I intend to become a Forensic Laboratory Scientist, and exposure to the scientific process will be of great benefit to my future endeavors.

During high school, I had the exceptional opportunity to participate in research at the Genius Olympiad 2014, Global Environmental International Fair in Suny, New York, where I obtained an Honorable Mention, being ranked in the top 20% (top 50) of 328 projects from 57 countries. This experience taught me that I have very limited knowledge in many areas of scholastic research. The SOAR research program is a means to expand on this knowledge. The more well rounded a person is, the more likely he can cognitively process complex information. I wish to improve my knowledge of all fields in order to be more competitive in graduate school and ultimately in the workplace.

I anticipate that the SOAR program will help me learn to express myself in a manner that is appropriate for scientific research. The sciences have their own specific language and means of expressing this language. This is a key factor for me when examining the SOAR program, as all results have to be presented not only to faculty members, but also to students in other disciplines, providing the opportunity to become more adept at speaking to different audiences. This is a skill that I believe will be highly beneficial for my planned career in Forensic Science.

My research program for this project will include handling different arboreal snake species, learning to use digital video cameras to record prey capture and manipulation, analyzing the resulting data using "Tracker" software, learning snake head anatomy, and understanding how these structures function during feeding.

Expectations
I anticipate that the SOAR research project conducted with Dr. Irish will increase my knowledge of the scientific method, and improve my critical thinking, analytical skills, and problem-solving ability. I am excited at the prospect of working with an experienced mentor. I anticipate that the SOAR program will increase my knowledge in an area I know little about, as well as increase my ability to present all findings to different audiences. SOAR is an opportunity to expand the mind beyond its boundaries by

applying learnt work to practical situations---as an unknown author once said: “A mind when stretched by a new idea never regains its original dimensions.”