SOAR Research Proposal
Summer 2016

Extreme kinesis: a comparative study of prey handling in snakes

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

Students: Raymond Morales and Josh Levano

Project start date and duration: May 31, 2016 (10 weeks)

Background for the project: Snakes have highly kinetic skulls. 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. Because the snout is loosely tied to the upper jaws by connective tissues, we expect that the snout will passively track upper jaw movements. The ability of the snout and upper jaws to move freely is an integral part of the unique unilateral feeding mechanism of snakes, but for burrowing snakes like sand boas, having a collapsible snout could be a problem. Are snout movements in sand boas constrained by structural modifications that resist the stresses of burrowing?

Data from SOAR projects in 2011, 2012, and 2014 indicate that contrary to our initial expectations, the snout does *not* closely track the upper jaws in sand boas----in fact, when the mouth is opened, the snout is raised and the upper jaws are depressed (i.e., snout and upper jaws move in opposite directions). We also found that snout elevation in sand boas is comparable to published records for non-burrowing snakes, but snout twisting (rotation around a longitudinal axis) is very limited, suggesting that in sand boas, the snout and upper jaws show surprising independence of movement, and the snout may be more mobile than previously thought. How do the movements we observed compare with other snakes?

My research students and I have already done some preliminary comparisons, but more data on more species are required. As the phylogenetic relationships of sand boas are currently in dispute, it is not clear what species to choose. We initially looked at *Boa constrictor*, as this species is common and easy to maintain in the lab. To our surprise, we found *Boa* to be capable of extraordinary snout twisting during swallowing---far beyond what has been observed in other snakes. The question now becomes: Is snout twisting constrained in sand boas, or does *Boa constrictor* exhibit extreme kinesis?

Description of proposed summer 2016 SOAR project:

Results from previous SOAR projects are intriguing, but to place these results in an evolutionary context, we need data on more snake species, especially non-burrowing sister taxa (other booid species) and other burrowing snakes. The students will work together to record feeding in a variety of booid species; the students will each then choose a promising species to analyze further. 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 snout and upper jaw movements, timing of events, etc.
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 species with previously collected student data on sand boas (*Eryx* sp.), non-burrowing boas (*Lichanura trivirgata, Boa constrictor*), and more distantly related non-burrowing colubrids (*Pantherophis guttatus*).
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 2011 and 2012 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.

Experimental animals: Some of the snake species needed for this project are currently housed in the animal facility at Moravian College. Species to be used for comparison will be borrowed from the snake facility at Lehigh University. 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 2016 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 guide the students in their search for background literature, instruct them in experimental techniques and use of specialized equipment, assist in data collection, data analysis, and appropriate care of animals, and help them prepare their results for presentation.

Student role and responsibilities: The proposed project is part of an on-going research program, but Ray and Josh 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 and choose species to be studied.

Weeks 2-8: Record 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:

Ray and Josh are both currently planning to go to dental school, so familiarity with the techniques of gross dissection and experimental morphology should have particular relevance for them. Ray and Josh took General Zoology (Biology 112) from me and Ray has also taken Vertebrate Anatomy (Biol 310), so the students have had important background material that should help them understand the context of this study. However, 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 Ray and Josh more competitive in applying to dental school, and better prepared to succeed. They will present their work for scholar's day at Moravian College, as required, and for an audience of peers beyond Moravian College, such as the National Conference on Undergraduate Research and the Lehigh Valley Evolution and Ecology Symposium.

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 biology-bound 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: ***Extreme kinesis: a comparative study of prey handling in snakes***

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$ 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 2016

Extreme kinesis: a comparative study of prey handling in snakes

Student: Josh Levano
Major: Biochemistry
Year of Graduation: May 2017
Faculty mentor: Dr. Frances Irish
Request for on campus housing: Yes

As a junior at Moravian College majoring in biochemistry, I feel that SOAR is a vital opportunity for me to be engaged in research that is geared toward my field. This will be my first time doing research and I want to grasp all the knowledge I will learn from this experience and apply it toward the future (specifically in graduate school). Getting the chance to become more involved in my interests without being in a classroom all day will be quite thrilling for me.

In addition, many doors can open in doing a SOAR project. My life goal is to go to dental school and become an oral surgeon, or at least a general dentist. SOAR can help guide me to ease the difficult transition of going from undergraduate to graduate school by making me feel more comfortable and better prepared when approaching independent studies. SOAR can also grant me the opportunity to work closely with faculty and participate in their research. I particularly became fond of Dr. Irish's research because anything that has to do with studying animals is an automatic interest for me. There is always something distinctive or new that can be discovered from animals, physiologically or structurally. I realized that Dr. Irish's research involves measuring jaw and snout mobility and this caught my interest so I read more about it. I love the fact that we will actually be able to work with snakes and record how they capture and swallow their prey. The small details, such as the animals' behavior, are what I find most amusing. Plus, having an interest in dentistry, it would be nice to learn more about the structure and function of the jaws of species other than humans.

Taking this huge step in my undergraduate career is important to me because I will gain knowledge, not just in research, but for my future scholastic goals. I am aware that there is a presentation after doing the research, so being a timid type of student, I feel like this presentation at the end of the SOAR project, as well as many others in the future, will benefit me in becoming a better presenter and help me step out of my "comfort zone". Because, in reality, the more I practice, the more comfortable I will feel presenting. No matter what I do or where I go, presentations will be required, and SOAR will help make this task much less strenuous. I also hope to get a good understanding in how to explore new ways to do research, and engage in different methods for approaching a new discovery. Furthermore, this challenge will strengthen my skills in analyzing data and executing new research methods. So, to conclude, I feel like SOAR will allow me to gain not only research skills, which will teach me to think in a different

way, but a lifelong learning experience in intellectual involvement and personal interactions, whether it is with other students or coworkers in the future.