A Role for History and Philosophy of Biology in Exploring New Questions in Biology

Melissa A. F. Daggett

Department of Biology, Missouri Western State University, 4525 Downs Drive, St. Joseph, MO 64507

Corresponding Author: daggett@missouriwestern.edu

Abstract: A number of current reports are challenging educators of undergraduate biology students to increase the role, interactions and approaches of other disciplines. The goal stated in these reports is to produce a college graduate with the skills and competencies to solve pressing global problems such as producing ample food, fuels, and making health care available, while also preventing the degradation of the Earth's renewable resources. This perspectives essay presents the inspiration and motivation that resulted from the interactions and collaborations with faculty in philosophy. My goal is to describe how these interactions occurred and how it has helped to inform and guide me in the development and implementation of new biological questions that can be addressed by undergraduate researchers. It has also allowed reflection on how scholarly endeavors in biology and philosophy can complement each other.

Key words: interdisciplinary, undergraduate research, history and philosophy of Biology, *Daphnia*

INTRODUCTION

Recent reports have highlighted the importance of interdisciplinary and interconnected approaches with an increased focus on competencies in educating the next generation of biologists (American Association for the Advancement of Science, 2011; National Research Council, 2003 and 2009; Woodin, 2010; Labov, 2010). These reports also emphasize the interrelatedness of science, technology, engineering, and mathematics (STEM) courses as being critical for producing a college graduate with the ability to solve pressing global problems such as producing ample food, fuels, and making health care available, while also preventing the degradation of the Earth's renewable resources (NRC, 2009).

This increasing recognition of and emphasis on facilitating and promoting innovative collaborations between institutional academic departments, referred to as interdisciplinary collaboration, often implies expanding on and promoting the interrelatedness of questions and problems within the STEM disciplines. An appreciation and broader expansion of interdisciplinary collaborations into non-STEM fields should be supported and emphasized as well. Greater inclusion of non-STEM disciplines such as philosophy, history and literature, offers opportunities and insight into the exploration of even more questions and approaches. In addition, the influx of a wider range of novel ideas and approaches can encourage and enhance creative and critical thinking in ways that are applicable to solving problems that have the potential for highly advantageous societal impact.

This perspectives essay presents the inspirations and motivations I gained through interacting and collaborating with faculty in philosophy. These interactions have resulted in the initiation and development of a research project based on questions in biology that I was peripherally aware existed. In addition, the questions formulated and their natures lend themselves to the types of projects approachable to undergraduates. My hope is that through communicating an example of how my interactions and collaboration with faculty in a non-STEM discipline such as philosophy have enhanced ideas and opportunities for developing new undergraduate research projects, such interactions can be sought and applied by faculty at other institutions.

Initial Inspiration

During the spring of 2010, Missouri Western State University had begun a search to hire a new faculty member specializing in philosophy of biology. This individual would reside in the Department of History, Philosophy and Geography (currently the Department of Philosophy and Religion) and would be expected to actively interact and collaborate with faculty in the Department of Biology. In this situation, the promotion of interdisciplinarity began through a general invitation to biology faculty members to serve on the search committee for hiring this faculty member in a department outside of biology. This was a genuine committee appointment, not a mere token representative. The biology faculty participated in the candidate interviews, attended their seminars, and provided legitimate input regarding which candidate to hire.

This was a beneficial interdisciplinary experience from my perspective, in that it was during one such candidate's seminar that I found myself reevaluating my understanding of the biological species concept. Prior to this presentation, I had taken for granted that there was one broadly accepted species concept (Mayr, 1999). In most of the courses

I teach, I spend the most time at the cell and molecular level of the biological hierarchy and my assumption was that biologists had a fairly uniformly accepted definition of a species, especially in the era of genome sequencing. Catherine Kendig's talk revealed that the species concept is a major area of discourse with over 27 competing definitions of a species (Claridge et al., 1997; Wilson, 1999; Wilkins, 2009).

IMPLEMENTATION

The *Daphnia* Project

After Kendig was appointed to the faculty position in Philosophy, we engaged in subsequent discussions of possible research projects that could be done during the following summer to highlight and examine the species concept in collaboration with our students, as well as for our own professional understanding and scholarship. Kendig and I discussed the use of a well-studied organism, *Daphnia*, by developing an approach to the taxonomic problem that could complement the methods traditionally used in a cell and molecular laboratory. Throughout the academic year, we collected and read references and practiced culturing *Daphnia*. I continued to learn how philosophers of biology looked at scientific questions and Kendig learned the details of properly performing procedures in the biology laboratory, including bringing her cross-listed class, BIO/CHE/PHL 308 History and Philosophy of the Natural Sciences into the lab to "do science" several times.

Our first approach was to establish clonal populations of laboratory *Daphnia* and see if we could expose them to different kairomones, the chemical cues released by predators that induce beneficial changes in daphnid phenotype. We then considered having students observe for changes in phenotype following which they could then question how changes in morphology without a change in genomes could influences their interpretation of species identification (Tollrian and Harvel, 1999, Tollrian and Leese, 2010, Hanazato and Dodson, 1995).

Following multiple somewhat disappointing attempts, we developed an alternative plan that turned out to be what ecologists refer to as a common garden experiment (Mettelbach et al., 1999; Thorpe et al, 2005). We would collect *Daphnia* from one or more of the nine ponds we have on campus; key out the *Daphnia* morphologically using available taxonomic keys; and then attempt to culture clonal populations over the summer in a common controlled media and see if they would morphologically change back into some preexisting form. Learning the methods to collect and culture the *Daphnia* and to determine the chemical structure and mechanisms of kairomone action relied significantly on the more traditional form of interdisciplinary STEM collaborations, in that we invoked the help of an organismal biologist in culturing the *Daphnia* and organic chemists in determining which molecular structures and chemicals could potentially induce phenotypic change in our *Daphnia*.

While Kendig and I viewed the *Daphnia* project as a complementary interdisciplinary project, we recruited undergraduates to participate in two distinct undergraduate summer research teams. The biology team would question the identification of *Daphnia* species by focusing on techniques and procedures traditionally used in a cell and molecular laboratory, while the history and philosophy of biology team would pursue the question using more interdisciplinary methods as described in Kendig et al.(this issue). This sister team approach demonstrated and reinforced our view that interdisciplinary collaborations do not have to completely merge disciplines in order for the faculty and student participants to benefit from exchanging ideas and pursuing answers to questions specific to their own discipline. Both teams received institutional funding in terms of salaries, tuition, and supplies in order to carry out their projects.

Kendig et al. provide a concise description and review of the use of *Daphnia* in proposing new approaches to answering questions associated with phylogenetic classifications as carried out by the history and philosophy of biology team. Their recovered methods of observing living organisms supplemented the biology team project in which we applied current specialist science methods for analyzing the *Daphnia* proteome by combining a common garden experimental approach with the cell and molecular techniques of isolating and analyzing nucleic acids and proteins (Frohlich, 2009; Tautz, 2011; Colbourne et al. 2011).

The Biology Team

The biology team consisted of three undergraduates, all seniors, graduating with degrees in biology the following fall semester. The students were provided with a one page set of instructions at the beginning of the summer (Appendix 1). The requirements were simple and concise in order to increase focus and yet provide flexibility. The specific aims of the biology team were: 1. to collect, identify, and photograph representative *Daphnia* from local aquatic habitats, 2. to develop standardized culturing methods for maintaining isolates in the laboratory, and 3. to develop and perform various cell and molecular techniques to characterize each species. These aims were designed to complement the methods and techniques being applied by the history and philosophy of biology team.

The students on the biology team were able to complete all three specific aims and were able to present a poster of their results at a University-wide undergraduate research symposium (data not shown).

Procedures for using new equipment were developed and student-tested including one for a microtiter plate protein assay that was used as a lab practical for the introductory BIO 106 Principles of Cell Biology students. Another procedure developed and modified for student use was a method for collecting protein samples from individual *Daphnia* that could be used in monitoring changes in the *Daphnia* proteome through SDS-polyacrylamide gel electrophoresis (Frohlich et al. 2009). The new student-tested procedures are currently being used in an assessment of student gains in laboratory skills in an introductory cell biology course (unpublished results).

Many published reports point out that undergraduate research experiences be relevant and accessible to a broad array of students and that they be based on scientific evidence for how people learn (National Research Council, 2000). Projects should also include interdisciplinary and interconnected approaches. While both the biology and the history and philosophy of biology research projects were carried out alongside each other in the same lab space, my interest and focus was mostly on the complementary role the biology project had on the history and philosophy of biology project. My students engaged in an authentic undergraduate research experience. They also benefited from the interconnected approaches provided by the two different disciplines, while increasing their competency in performing specific laboratory skills. In addition, I believe the experience I had in working with a faculty member outside my own specific discipline has given me the awareness and opportunities to explore new questions that I may not have otherwise thought to ask.

In conclusion, this perspective described the inspiration, motivation and the undergraduate research projects that resulted from an interdisciplinary collaboration between faculty from two different disciplines one in biology, a STEM discipline and one in philosophy, outside of STEM. I would like to encourage faculty at other undergraduate institutions to explore possible opportunities to strengthen the interdisciplinary connectedness with non-STEM courses and to consider the benefits such interactions have on us, the faculty, and on the students we educate. A greater emphasis on interdisciplinary approaches will continue to be critical for helping our students become able to solve the pressing global problems facing us today and in the future.

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APPENDIX

Initial references to read and look over:

Basic Daphnia Biology

http://www.ncbi.nlm.nih.gov/books/NBK2042/

Identifying zooplankton:

An Image-Based Key To The Zooplankton Of The Northeast (USA)

http://cfb.unh.edu/cfbkey/html/index.html

Summary procedure (may vary slightly for each individual)

In the field:

- Pick a minimum of one body of water (on campus or elsewhere) in which to collect your daphnia sample.
- Collect a minimum of one water sample with daphnia using a plankton net.

In the lab:

- Set up 10 small petri dishes with daphnia water (see recipe below).
- Place one isolated daphnia/dish.
- Use the on-line key and other resources to learn the terminology associated with daphnia anatomy and to identify the Genus and species of the daphnia in your sample(s).
- Take pictures and make multiple drawings of your samples to document and support your identification.
- Continue to observe and document the life cycle and population growth of each of your daphnia "clones". Pay special attention to any changes in morphology throughout the summer.
- Learn and perform at least one specialized cell and molecular technique as your cultures grow and more individuals within a clone become available. Possibilities include the analysis of gene expression through PCR, SDS-PAGE, Western blotting and immunofluorescent microscopy.