



## Commentary on Pomfret High School's Research Program and Student's Article: "The Effect of Red Light Stimulus on the Foraging Behavior of *Drosophila melanogaster* Through Measuring the Proboscis Activity"

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Perhaps you too have heard the old line about graduate school and the pursuit of scientific knowledge through research: the training of scientists forces them to learn more and more about less and less. And so it is against that prejudicial backdrop, and the growing need to develop empowered and savvy citizens capable of inventing the work and skill set of tomorrow, that we teach science in the United States. It is a tall order indeed, and many metrics would suggest that we are failing at that task as a country.

At Pomfret School, a coeducational boarding and day school for grades 9-12 located in northeastern Connecticut, we believe that research and investigation are essential tools in building that inquisitive, worldly, engaged, and nimble thinker needed in the world. As a result, the science department here strives to combine inquiry and experimentation with content, choosing to create environments where students can build their own knowledge and receive quality coaching, author and address probing questions, and explore firsthand how the world works.

Hokyung Keum is a product of that climate, and her paper, on the response of fruit flies to visual and olfactory stimuli, can be used to debunk that old line paraphrased above. Enrolled during her junior year in a new course, Directed Science Exploration, Hokyoung researched behavioral studies and created a testable question of her own, asking whether *D. melanogaster* can link one positive stimulus to another, effectively testing if fruit flies can learn to associate red light and food. Raising the question is one thing; figuring out how to "ask" the question in a way that yields useful data is another thing all together. Ms. Keum needed to create a protocol for manipulating her flies and how best to assess the level of the response, a process which took several iterations and called upon her to invent, test, modify, and refine her approach. In completing that task, she called upon outside mentors and local experts, brokered relationships and build a supportive network of scientific support, and experienced the non-linear path of science and discovery. This is a far cry from the conformational labs that most students experience in their science classrooms; Hokyoung, and to a lesser extent her peers at Pomfret School, knows that she can pursue an answer without knowing the outcome or the pathway in advance.

Science is littered with examples of people building something new to answer a novel question, and it is this very ingenuity and resolve that we should be teaching in the science classes of this country. Kids need practice building solution strategies; they need opportunities to make mistakes, devise data collection methodologies and crunch data, assess its quality and significance, and to determine alternative approaches and the next steps that can further test emerging understanding. Doing so gives students the confidence to discover and piece together meaning—it is the very same problem solving and invention that the 21st century skill set demands.

The take home message for Hokyoung is not really connected to fruit flies at all. Rather, it is the knowledge and confidence that she can map out and conduct a novel inquiry event and call upon her considerable problem-solving skills to achieve success. What better lesson could we possibly seek in science education?

## Commentary on the Jericho High School Science Research Program

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Jericho's Science Research Program enlivens students to create a new and endearing thirst for learning and achieving mastery in various science disciplines. Course skills Jericho students acquire include: pinpointing a science topic of interest, identifying current trends in the science, create a pivotal question to investigate; established after reading ideas presented in the popular science articles (Science



News, Science Daily), complete in depth “dissection” of journal articles (using Pub Med and Scopus), explain each journal and aspects of the methodology (including experimental tools used), explain the relevance of the results and why the future investigations are needed for each journal read. By the end of a student’s sophomore school calendar year, they will have read upwards of 25-30 journals to understand the current science related to their topic and relate these scientific works to the answering their pivotal question.

The Jericho HS Research students then present synopses’ of journals acquired in PPT presentations and begin writing a skeleton paper which includes an introduction/background information, rationale of the research, brief methodology (referenced and properly cited), and ideas for future investigations learned from literature reviews. Finally they are asked to develop research plans and to conduct “In-House” research experiments for the topic of their choice. Lastly, they are encouraged to conduct wet bench research during the summer at a regulated research institution.

Our students are intellectually curious and often show a keen insight of materials presented. They understand the meaning of hard work and getting the job done in the delegated time frame. In total, our program stimulates the minds of these young adults to identify solutions to the many issues our country is facing today and will face in the future. Our article discusses the implementation of various methods to achieve high-performance water filtration and efficient heavy metal adsorption. Currently, the effects of the global water crisis are becoming increasingly severe, so water purification is a very prominent topic in our society.

## Student Led Research at Oregon Episcopal School

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The expectations of today’s high school student are many and varied. As such, it may be easy for a student conducting an independent research project to focus on the end product such as the academic grade and/or potential awards from science fair competitions. Yet, I continue to be impressed with the unique yet relevant studies many students decide to pursue. The study done by Andrea Boorse represents a sincere effort to understand the impact of human endeavors on the natural world. She developed this study soon after the oil spill in the Gulf of Mexico when the topic of the effect of oil dispersants on living species arose. Having just entered the ninth grade, one might think a student would not have the knowledge base or laboratory skills to conduct a research study on the bioconcentration of oil dispersants in oysters. I myself, a physics teacher with a degree in materials science and a background in steelmaking and semiconductor processing did not have the expertise needed to design a study of this nature. Yet, for this student led project and others that I have guided over the past three years, I found myself compelled to try. The end result is inspirational.

Incorporating student led science research projects into the core science curriculum has been a tradition at Oregon Episcopal School for nearly 30 years. It comes with its own challenges for a teacher such as managing 40+ projects a year as well as a reduction in the traditional curriculum taught, but the benefits are immense. This is particularly evident at the annual Aardvark Science Expo, an all day school-wide event where students present their projects before judges, teachers, students, and parents. It is truly a celebration of what these young people are capable of and a hint at what the future holds. Many of our students may not go on to become scientists, doctors or engineers, but having experienced this truly inquiry form of learning, we feel they will have the knowledge base and tools to apply critical thinking to their world. This fills me with a sense of hope and purpose and for that, I am grateful.

## The Research Program at Amity Regional High School

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The research program at Amity Regional High School in Woodbridge, CT is an honors level elective course which students take in addition to their regular, traditional course load. Students entering the program must be recommended by their eighth grade science teachers and have outstanding academic grades – particularly in math and science. The program offers an opportunity for students to create and conduct authentic science research and is recommended to be a three or four year commitment. Year 1 is primarily an overview of research design, data collection and analysis as students become familiar with the scientific method. In subsequent years, students secure a mentor outside of the program to assist with design and experimentation of their authentic research.



## Student Research at Phillips Andover Academy

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While many departments and programs at Phillips Academy feature faculty members and students who are deeply engaged in research projects, the Division of Natural Sciences has enjoyed an especially robust research program in recent years. Within the last decade, several instructors have joined the science faculty following careers in research, bringing their own special interests and expertise to the courses offered in the Division. As a consequence, Phillips Academy's Division of Natural Sciences has seen an increase in active research, even beyond the strong existing research programs already in place. The signature course for research in the Division is Biology 600, a dedicated laboratory course normally reserved for seniors (or accelerated 11th graders) who have completed most of the available advanced classroom coursework in biology. Beginning with instruction on model systems and techniques widely used in professional laboratories, students enrolled in Biology 600 embark on independent research projects of their own choosing. In past years, students have explored a wide range of topics, from the roles that specific genes play in the growth of brain cancer cells, to the genetic controls promoting successful regeneration of motor neurons in nematodes, to novel gene targeting strategies for the production of "humanized" proteins in bacteria.

One recent study from our lab, an investigation into potential role(s) for the protein Survivin in glioma cell proliferation and migration (Montana), is presented in this issue. Generally speaking, Biology 600 students spend two to three trimesters working on their projects. Along the way, they become active participants in the broader scientific community, communicating with professional laboratories and companies and learning the refined art of collaboration. Each year, students present their findings before a collection of peers, faculty, staff, alumni and administrators, at a special event that celebrates their efforts and achievements.

The Abbott Independent Scholar Program offers additional support for independent research (in place of standard coursework) here at Andover, and many opportunities to execute experiments on a smaller scale are also presented to students within the framework of existing courses. For example, the focus of the Biology 580 course—the final term of a three-term advanced sequence that builds from cellular and molecular biology to ecology and evolution—is an experimental research project into an ecological topic of the students' choosing that is conducted over the course of most of the spring term. The current issue of the Journal of Experimental Secondary Science features an article (Howard et al.) that was the product of one such project: an investigation into the effects of soil conditions on thigmotropism (rapid snap-trap closure) in Venus flytrap plants. As testament to the creativity of students involved in these projects, the flytrap experiments were conceived, designed, and executed completely by the students themselves.

Even as future sections of the Biology 580 course will work on student-driven ideas for ecology projects, and Biology 600 still presents opportunities for long-term, in-depth research, students continue to express interest in model systems and experimental work that will push the boundaries of the research offerings at Phillips Academy. Indeed, a trio of students who have taken Biology 570—the human anatomy and physiology course—are currently writing proposals for an upcoming Independent Project that will focus on recording muscle potentials from genetically-modified fruitfly larvae whose motor neurons contain photo-activatable ion channels to allow for remote muscle stimulation.

We expect that, as long as Phillips Academy students remain curious and motivated by the promise of discovery, and faculty members of the Division of Natural Sciences remain committed to their own professional development, as well as to mentorship and the teaching of practical science, we will continue to see expanded opportunities for students to conduct even more diverse projects in various biological disciplines in coming years.

\*More information about Independent Research at Phillips Academy is available online:

<http://www.andover.edu/Academics/NaturalSciences/IndependentResearch/Pages/default.aspx>



## Teen Research and Education in Environmental Science (TREES): A Summer Program for High School Students

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*—where there's an unexpected, exciting result, it's just the same thrill all over again. You go home, and you think about it when you go to sleep, and you think about it when you wake up in the morning, and you know there is something new in the world. —David Baltimore, Nobel Laureate, from a 2006 interview with Discover Magazine.*

The difference between students and researchers is that the former are consumers of knowledge, while the latter are producers of knowledge. The transition from a student to a researcher is usually carried out through mentoring programs. After classroom training, there is a long period of individual mentoring in graduate school and then, in many fields, yet more mentoring in postdoctoral training. Most research scientists cite their first experience in a lab as motivating them to choose a career in research. To provide that first experience to a young group, in the summer of 2007, the Center for Excellence in Environmental Toxicology, Perelman School of Medicine of the University of Pennsylvania launched a community outreach education program for high school students called the Teen Research and Education in Environmental Science (TREES) summer program. The TREES program is a unique hands-on research experience for high school students that introduce them to laboratory science. About seven students are recruited each year from local high schools for the ~five week program. They are taught by graduate student mentors, alumni high school student mentors and faculty members, all of whom volunteer their time to guide the students one-on-one or in the small group.

#### *TREES Academic program*

There is a daily lecture on an environmental issue. TREES students also watch and discuss movies about environmental issues (e.g. An Inconvenient Truth, Thank You for Smoking). Other activities teach “survival” skills such as laboratory safety, library research, internet research, scientific writing and presentation skills. There is also a college admissions workshop, a career discussion, several responsible conduct of research discussions, a library tour and a Penn campus tour. Twice each week TREES students participate in an activity with undergraduates (who intern in labs through the STEER program), once to hear a member of the Penn faculty give a cutting edge lecture and then again to travel off campus for a field trip. Students also prepare reports on a natural product that originated from an environmentally sensitive region of the world.

#### *TREES Research program*

Since most students are in a research laboratory for the first time, TREES labwork begins with about two weeks of structured laboratory exercises to teach basic lab techniques such as pipeting, weighing, sterile technique, and several spectrophotometer level assays. The structured laboratories also include safety training and instructions on using common laboratory equipment. This sets the basic training for what is the most unique aspect of the program: an individually guided research project on a topic chosen by the student. The projects are developed in consultation with the mentors and faculty and then executed by the student. Students present their results in a report, a poster and a PowerPoint presentation to the group and invited guests in a student run symposium. The projects cover a range of environmental topics; as the publications at the end indicate, students have worked on CO<sub>2</sub> sequestering, food safety and chemical carcinogens, as well as arsenic poisoning, phosphate trapping and biofuels.

#### *Beyond TREES*

Science does not end with their laboratory experience, as the data collected must be analyzed and presented according to scientific standards. Students work with their mentors after the program to develop projects for public presentations, science fairs and their senior thesis. Others have found creative ways to bring the message of their project to their schools. For example one student who made and tested biodiesel as his project, organized a used cooking oil recycling collection in his school. TREES projects have earned students numerous awards back at school and in local science fairs; several won invitations to national competitions and scholarships. Three, including Jeremy Wortzel, whose paper is published in this issue, published their work in peer reviewed scientific journals. The program is currently funded by a grant from the National Institute of Environmental Health Science (NIEHS).

#### *Applications to TREES*

Interested high school students from the Philadelphia area should download an application from the website at: <http://www.med.upenn.edu/ceet/TREES.shtml>. The applications require an essay, a copy of the transcript, and two letters of recommendation. There is no tuition or fees for TREES program. Inquiries: [mytrees@mail.med.upenn.edu](mailto:mytrees@mail.med.upenn.edu)

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