with a more genuine research experience, one that is consistent with the experience of an academic presenter at a professional conference.

This redesigned model has also helped to create a culture in which research is valued and psychology is viewed as a science. We now have a directive to increase opportunities for research that will be infused into upper-level courses in the major. Last semester, 88.89 percent of instructors of upper-level courses incorporated skills and knowledge related to research methods into their courses (e.g., having students use library resources to conduct an effective literature search or synthesizing findings across multiple research articles). Instructors have also designed assignments that required students to collect and analyze data on a small scale, and then assess the validity and reliability of established measures and, ultimately, create and present an evidence-based poster or paper.

Data from our annual senior exit survey (*n*=190) suggest the majority of our students continue to have meaningful research experiences after completing our redesigned research-methods course, with 95 percent reviewing primary scientific literature, 75 percent contributing to a poster or paper presented at a conference, and 64 percent attending a conference where their research was presented. These are remarkably high percentages, given that only 26.15 percent of students surveyed reported participating in our undergraduate research experience course, in which students work on original research with faculty. Thus, the practices incorporated into this redesign of the undergraduate research methods in psychology course provide a strong model for both teaching research methods and incorporating meaningful undergraduate research experiences into the major.

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A Community Model for Course-based Student Research That Advances Faculty Scholarship

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Educator-scientists are well aware of the many pedagogical benefits of engaging undergraduates in original scientific inquiry. However, doing so in a classroom setting to reach more students is challenging, time-intensive, hard to sustain, and intellectually draining for busy faculty members who struggle to balance the demands of teaching and research. Despite their best intentions, many faculty members who teach laboratory courses resort to straightforward "cookbook" lab exercises that require little to no problem solving and have ready-to-go teaching materials but do not provide students with experience in original inquiry.

To address these challenges, we formed a vibrant learning community of faculty members at multiple institutions. In our group, the Ciliate Genomics Consortium (CGC), all faculty members use a common model organism—*Tetrahymena thermophila*, a common single-celled inhabitant of pond water—in their research. Over the past 11 years, the CGC has developed a modular curriculum that exposes undergraduates to original research, contributes to scientific knowledge, and advances the varied research interests of participating faculty members.

The CGC curriculum includes five core modules using *Tetrahymena:* testing in silico gene models by reverse transcriptase polymerase chain reaction, determining gene expression profiles, assessing effects of gene knockouts, determining protein localization, and identifying protein interaction partners. Each faculty member may apply any combination of modules (designed for standard three- or four-hour laboratory sessions) to study any set of genes relevant to his or her particular research interests. We designed the modules to be highly flexible so faculty members can use them to address a broad range of biological questions in cell biology, molecular biology, genetics, biochemistry, and introductory biology courses.

For example, one class might use the protein localization module to investigate where proteins of interest act in a cell by tagging them with a fluorescent protein and examining localization in live cells by fluorescence microscopy. Another class might use the gene expression module to monitor changes in expression of selected genes when cells are exposed to environmental stressors or when growing in competition with another species. The flexible and modular nature of the curriculum has promoted its adoption, in one form or another, at 22 institutions to date.

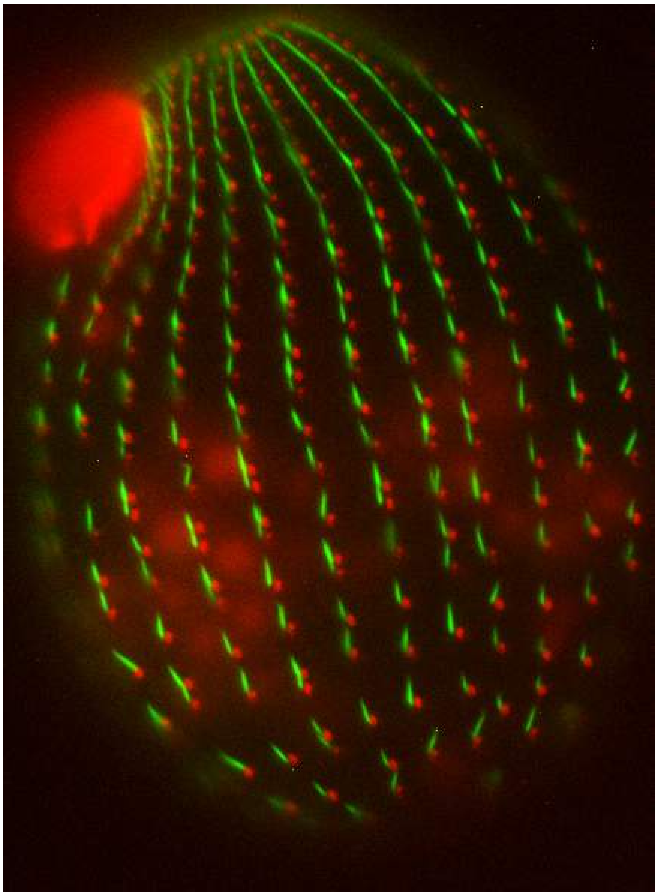
We have identified five key benefits of the CGC curriculum. First, it is sustainable over the long term. Currently, around 100 students per year each investigate a different gene. Of the approximately 28,000 genes in the *Tetrahymena* genome, the functions of only a few hundred have been characterized. Thus, even if the CGC model is expanded tenfold, initial studies on every gene in the genome will require nearly three decades to complete.

Second, students are engaged in original research and take ownership of the new knowledge they create. Validated assessment instruments such as the Classroom Undergraduate Research Experience (CURE) survey (Denofrio et al. 2007) and Student Assessment of Their Learning Gains (SALG; salgsite.org) strongly support the idea that these students broaden their understanding of the scientific process and other measures that are key to retaining students' interest in science majors. In the past three years, we have encouraged student ownership of their research by creating an Internet database (suprdb.org) on which students can immediately publish research reports describing their findings (Wiley and Stover 2014). Students know that their work will be accessible to the broader community because the report pages are linked to the official *Tetrahymena* Genome Database (Stover et al. 2012).

Third, educator-scientists can leverage classroom-mentored research to advance their own areas of inquiry and/or to broaden their research programs. For example, a study initiated in a CGC course resulted in the first published characterization of the *Tetrahymena* nuclear import machinery (Malone et al. 2008). Even when course-based research projects have been less successful than this example, faculty members have been able to test genes of interest for potential follow-up or exclusion from their research efforts.

Fourth, the CGC curriculum has promoted new research collaborations, distribution of results and reagents, and sharing of technical skills among labs. Multiple student exchanges have occurred in which an undergraduate researcher visited a consortium member's laboratory to learn new techniques and then took that skill back to the mentor's lab in the home institution. In a particularly wide-ranging, multiyear example of collaboration and sharing of reagents, undergraduates at Drake University performed biochemical purification of cytoskeletal proteins. Faculty and students at St. Olaf College then identified the proteins by mass spectroscopy and sent the list of proteins to Washington University in St. Louis, where students in a molecular cell biology lab course fluorescently tagged and determined the subcellular localization of the proteins (Figure 1). Finally, the faculty member at

Figure 1. Localization of two *Tetrahymena* cytoskeletal proteins in classroom research. Kdf1 in green, Epn1 in red.



Washington University in St. Louis sent the student-generated *Tetrahymena* strains to Drake and St. Olaf, where students are performing follow-up analyses.

Lastly, the research performed by students in CGC courses has advanced scientific knowledge. Beyond the classroom, a gene-tagging strategy developed for undergraduate courses has facilitated discoveries in the broader community (e.g., Cole et al. 2008; Bright et al. 2010). Moreover, roughly 300 students have published their work on suprdb.org, more than 80 students have presented their work at scientific conferences, and numerous students have been included as authors on or acknowledged for their contributions to 10 manuscripts.

Our strategy, then, has proven to be mutually beneficial: a win for the students, who learn how knowledge is constructed; a win for the individual faculty members, who use student discoveries to advance their own scholarship; and a win for the broader scientific community, which gains useful new knowledge. Although the CGC curriculum is focused on *Tetrahymena,* the affordability of genome sequencing means that this research/education model should be transferrable to many other communities of biologists working on a common organism. The only other thing they need is to share a passion for teaching—and learning from—the next generation of scientists.

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