Long term impact of intensive post graduate laboratory training at the Cold Spring Harbor Neurobiology of *Drosophila* summer course

Sarah Ly[1], Karla Kaun[2], Chi-hon Lee[3], David Stewart[4], Stefan R. Pulver[5#] and Alex C. Keene[6#]

1. Center for Sleep and Circadian Neurobiology, University of Pennsylvania, Philadelphia, PA 19146
2. Department of Neuroscience, Brown University, Providence, RI 02912
3. Institute of Cellular and Organismic Biology, Academia Sinica, Taipei, Taiwan, 11529
4. Cold Spring Harbor Laboratory, 1 Bungtown Road, Cold Spring Harbor, NY, 11724
5. School of Psychology and Neuroscience, University of St. Andrews, Fife, Scotland, KY16 9AJ
6. Department of Biological Sciences, Florida Atlantic University, Jupiter, FL 33401

address correspondence to sp96@st-andrews.ac.uk and KeeneA@FAU.edu

Abstract

Intensive postgraduate courses provide an opportunity for junior and senior level scientists learn concepts and techniques that will advance their training and research programs. It is commonly assumed that short intensive courses have positive impacts within fields of research; however, these assumptions are rarely tested. Here we describe the framework of a long running postgraduate summer course at Cold Spring Harbor and attempt to quantify the impact made over its history. For over three decades, the *Drosophila* Neurobiology: Genes, Circuits & Behavior Summer Course at Cold Spring Harbor Laboratories (CSHL) has provided participants with intense instruction on a wide variety of topics and techniques in integrative neuroscience using *Drosophila* as a model organism. Students are introduced to the latest approaches for studying nervous system development, activity and connectivity, as well as complex behaviors and disease models. Further, students learn a broad range of methods, including genetic manipulation of genes and neurons, phenotypic analysis, electrophysiology, anatomy, and behavior. The course includes an intensive hands-on laboratory component, a lecture component by instructors and visiting experts, and an evening seminar series where groundbreaking neuroscientists provide their perspectives on how *Drosophila* neuroscience research fits into the larger context of discovery in neuroscience. Student surveys indicate a high level of satisfaction including improved career outcomes and a direct impact on publications. Analysis of student success reveals that over 64% of participants obtain independent faculty positions, suggesting this course has a dramatic impact on trainee outcomes. Further, we describe on-going efforts to enhance diversity and encourage access to scientific research at undergraduate-focused institutions. Together, our findings suggest that laboratory-intensive postgraduate courses provide a highly effective mechanism for scientific training that has lasting positive impacts on trainees.

INTRODUCTION

Research on the fruit fly, has played an important role in uncovering principles of nervous system structure and function. Fundamental insights include the first molecular descriptions of nervous system differentiation reviewed in [1], the identification and elucidation of axon guidance cues reviewed in [2] the first cloning of ion channels reviewed in [3] the first demonstration that SNARE proteins are required for chemical neurotransmission reviewed in [4]and the identification of single genes that regulate complex behavior (reviewed in [5–7]). More recent advances are focused on neural circuit function and the neuronal basis for complex behavior reviewed in [8] *Drosophila* often leads the way in the development of genetic technologies for identifying, manipulating and monitoring neural circuits [9] Furthermore, complex behaviors, including learning, decision-making, feeding, circadian rhythms, arousal/sleep, aggression, courtship, and addiction, are now amenable to sophisticated experimental analysis. Increasingly, a full understanding of the connections between genes and proteins, neural circuits, and emergent behaviors is attainable [10–14]. Importantly, conservation of both the genes that underlie circuit formation and function and the information-processing logic of neural circuits means that discoveries and technologies developed in *Drosophila* are often readily translated into insights into the mammalian nervous system [7,15–17]

Work in *Drosophila* has also made major contributions as a model organism in STEM education. For decades high school students and undergraduates have been taught principles of genetics through the use of *Drosophila* in classrooms. In recent years, *Drosophila* has also emerged as an extremely powerful model organism for teaching principles of integrative neuroscience. This emergence has been driven by several reasons: 1) *Drosophila* are inexpensive to rear and maintain, 2) their use does not require Institutional Animal Care and Use (IACUC) approval, 3) the research community is

committed to making genetic constructs freely available, 4) a rich array of tools are available for manipulating gene function as well as visualizing and manipulating the activity of neural circuits 5) electrophysiological and imaging preparations used in the research community can be exported to teaching laboratories at minimal cost, and 6) *Drosophila* show a rich repertoire of behaviors that can be easily measured with minimal equipment [18–24] All of these strengths combine to create an optimal platform for teaching trainees at all levels how to solve problems in neurosciences at the genetic, molecular, cellular, behavioral, and computational level simultaneously. These strengths also make *Drosophila* an ideal 'animal ambassador' for helping laypeople of all ages understand the value of basic research in invertebrate model organisms [20].

The growing diversity of genetic approaches and specialization of individual laboratories presents an impediment to scientific training. Creative and novel approaches to science require a familiarity with cutting-edge genetic technology and approaches in model organisms, yet this type of specialized coursework is not provided in most laboratories or training programs. Laboratory-intensive courses provide trainees with intensive research experience including exposure to research areas and techniques that may not be available at their host institution. The *Drosophila* Neurobiology Course has been held annually since 1983 and is an example of a short course that has made a sustained impact within a field. Each year, 12 trainees are selected through a competitive admission process to participate in the three-week course. Here, we describe current recruitment efforts, structure, and methodology. Further, we provide a systematic analysis of student satisfaction and long-term career success of participants. Our analysis reveals remarkable sustained achievement and highlights the potential of similar courses to promote catalyze scientific impact and promote diversity within the scientific community.

METHODS

Course Structure

This laboratory and lecture course is intended for researchers at all levels who want to use *Drosophila* as an experimental system for studying the nervous system. It is a modern, state-of-the-art laboratory course designed to introduce students to various preparations for studying *Drosophila* neurobiology. Students of the course learn how to examine the larval and adult *Drosophila* nervous systems in order to study development, neurophysiology, neuroanatomy, and behavior. Students learn a range of methods and techniques including genetic, electrophysiological, imaging and behavioral techniques. This balance allows us to maintain the in-depth nature of the course while expanding the breadth of topics covered. Daily seminars introduce the history behind special topics while providing updated the current knowledge by including recent contributions to the literature and interactive discussions about outstanding questions. Student discussion is actively encouraged and major emphasis is placed on experimental methodology. Guest lecturers provide original preparations for demonstration, experimentation and discussion, and direct laboratory exercises and experiments in their areas of special interest and expertise. Each lecturer provides a supplementary reading list and several background papers or reviews that students are encouraged to read before each lecture. Students are also provided with detailed protocols for all laboratory experiments to facilitate the transfer of their experiences in the course to their home labs, and if requested can also take with them cutting edge optogenetic, thermogenetic and genome editing tools that are rapidly advancing this field.

The material provided by instructors, both in lectures and in many laboratory exercises, is supplemented by evening seminars that provide specific information on the current status of research in the invited speakers' area of expertise. The invited speakers are strongly encouraged to devote more than a day to visiting the Laboratory, during which they spend

many hours informally discussing the participants' experiments in relation to their current research interests. Daily formal and informal discussions between students, faculty and invited speakers on the finer points of the techniques and concepts being taught in each course is a valuable source of intellectual stimulation. These discussions also allow the instructors and lecturers to provide insight and advice on how to address the specific problems being encountered by students in their own research. These facets of the program all contribute to the total immersion of the participants in the subject. Topics are covered to a depth that is not possible in other courses and workshops, and because of the unique atmosphere and tradition of Cold Spring Harbor, there is a very strong interaction between the instructors and participants. Participants are able to focus their attention on the scope of the course, without the distraction of other responsibilities, and are essentially forced to immerse themselves in the relevant methodologies and concepts. Living, eating and spending informal hours with the established investigators, the permanent staff and the frequent casual visiting scientists to Cold Spring Harbor allows the participants to absorb much understanding and enthusiasm both inside and outside the lab and lecture hall.

The *Drosophila* Neurobiology Course is designed such that students spend most of their time performing hands-on laboratory activities to consolidate information they learned during seminars about cutting-edge research and lectures of basic neurobiological, genetic, developmental, molecular and behavioral concepts. The syllabus is formulated so that students first learn the basic neurodevelopmental and genetic concepts prior to learning physiology, sensory systems, simple behavior, and then finally complex behavior. Typically, students receive two lectures in the morning: one on basic concepts, then one on cutting edge research techniques, then are in the lab all afternoon and into the evening. Approximately half of the evenings of the course have additional lectures designed to

expose students to exciting contemporary research in *Drosophila* neurobiology and give perspective on how this works complements work in other model organisms. The twelve students accepted to the course are encouraged to think independently and use cooperative learning to maximize their own and one another's learning.

A central goal of the course is to expose students to techniques that can be readily implemented at their home institution. The course covers a broad range of standardized techniques, such as Ca^{2+} imaging, neuromuscular junction electrophysiology, and behavioral analysis using cutting-edge genetic tools. In addition, we focuse on Do-it-yourself (DIY) systems for behavioral analysis, including use of 3D printing to construct behavioral systems [25,26]. The potential for students to establish similar DIY systems at their home institutions is emphasized, thereby increasing the impact of these techniques.

The CSHL environment

CSHL provides an optimal setting for summer courses. Faculty and students stay together on campus throughout the course, within walking distance from the teaching labs, seminar rooms, cafeterias, libraries and recreational facilities. This represents a significant investment in terms of resources and support and ensures that faculty members can focus completely on teaching. CSHL is a secluded, self-sustaining scientific environment; this helps students drown out distractions and fully immerse themselves in the course material. Importantly, there are multiple courses that run simultaneously, providing rich interactions with trainees with backgrounds in related research.

Admissions and recruitment

Applications are open to candidates at any stage in their postgraduate career from academia and industry within the United States and from overseas. Applicants are

176 required to supply a *curriculum vitae*, letters of recommendation, a statement of research
177 interests and specific reasons for wanting to take the course, as well as request for
178 scholarship aid. Requests for financial aid have no bearing on whether applicants are
179 accepted. Participants are selected by the course instructors on the basis of several
180 criteria including quality of proposed research, demonstrated need for training in specific
181 research area, Institutional/community impact of training, national versus international
182 reach, US underrepresented minority (URM) status, breadth of representation of scientific
183 approaches and gender balance. Course faculty make efforts to select multiple stages of
184 trainees, ranging from graduate students to senior investigators. This distribution offers
185 several distinct advantages: students and fellows often benefit from working closely in an
186 informal setting with more mature advanced scientists, particularly in terms of learning
187 approaches and priorities. Conversely, more established scientists respond favorably to
188 the high degree of enthusiasm and "willingness to try anything" attitude often ventured by
189 early career researchers. These interactions have consistently generated a dynamic and
190 stimulating environment that facilitates maximal exchange of ideas and philosophies within
191 the course.
192
193 **Admissions and recruitment of underrepresented minorities**
194 CSHL-wide diversity recruitment retention schemes are augmented by efforts specific to
195 the *Drosophila* Neurobiology Course. These including working with industry, non-profits,
196 and universities to encourage applications from diverse backgrounds. The course
197 leverages these connections to recruit the best URM researchers in the field.. Additionally,
198 the course recruits undergraduate educators to attend the course who can then
199 incorporate cutting-edge *Drosophila* neuroscience into course curricula at URM serving
200 institutions. This 'teach the teacher' strategy ensures that the course content propagates
201 to the largest possible number of URM undergraduates.

202 **Service evaluation**

203 The academic administration of the teaching program at CSHL is the responsibility of the
204 course instructors. The course curriculum is determined by the course instructors, and
205 progress is monitored by the senior administrative staff by discussion and evaluation
206 during and after each course with faculty, students, and guest lecturers (including former
207 instructors). The students complete anonymous course evaluation forms at the end of the
208 course with the primary aim of improving the quality of the course. In addition, feedback
209 is solicited from the wider community during biennial CSHL research conferences on
210 *Drosophila* neurobiology. The close contact between the CSHL Summer Program
211 leadership, course faculty, and research conference organizers also provides many
212 opportunities for informal course evaluation. All data collection, analysis and presentation
213 was performed in accordance with Cold Spring Harbor Laboratories IRB Protocol 17-019.
214

215 **RESULTS AND DISCUSSION**

216 **Course Participants**

217 Admission to the course is competitive, with an average acceptance rate of approximately
218 30% over the last nine years. From 2008-2016, the course typically had 12 students from
219 diverse career stages (Table 1). The majority of students (63%) were doctoral trainees,
220 with an additional 27% postdoctoral trainees and 9.4% senior scientists. The course has
221 also maintained gender and geographic diversity, with a nearly 1:1 male-female ratio, and
222 32% of students coming from outside of the United States.
223

224 **Instructors and Lectures**

225 The course faculty is formed by researchers who are active in complementary research of
226 fly genetics, neurodevelopment, physiology and behavior. The course is led by three to
227 four instructors (organizers), who collaboratively design the course syllabus, plan the

228 course schedule, and invite suitable lecturers, based on the current *Drosophila*
229 neurobiology research and student feedback. From 2008-2011, each year, approximately
230 sixteen lecturers gave both seminars and laboratory sessions, whereas an additional
231 ~eight lecturers gave evening seminars on cutting edge research in their laboratories.
232 Lecturers formed a cross section of the *Drosophila* community, coming from the United
233 States (83.6%) and outside the US (16.4%). They represent primarily research universities
234 (61.2%) and research institutes (37.7%), but also government (0.9%) teaching colleges
235 (0.9%). A range of career stages are represented from full professors (12.93%), and
236 tenure track faculty (58.7%) to postdoctoral fellows graduate students and technicians
237 (33.6%). Gender balance was actively encouraged in recruitment of course lecturers,
238 instructors and TAs, with an overall 60.3%/39.7% male female/ratio across 8 years.
239

240 **Student Satisfaction**

241 The perceived impact of the course on students was quantified through a standardized
242 questionnaire solicited each year from 2012-2016. The survey was designed to measure
243 both personal satisfaction and the perceived contribution of the course to the trainees'
244 career. Evaluation sheets were typically circulated on the last day of the course and
245 students were encouraged (but not required) to complete and return the evaluations
246 before they depart from CSHL. Importantly, evaluations are handwritten and completely
247 anonymous, thereby encouraging students to be open and frank in their comments. Each
248 evaluation includes a scoring system in response to questions about different aspects of
249 the course: 1 (needs improvement) - 5 (exceptional). Each evaluation also asked specific
250 questions requiring a written response. Evaluations were independently reviewed by
251 course instructors and by Cold Spring Harbor program staff within four weeks of
252 completion of the course to ensure significant criticisms may be addressed, as well as to
253 incorporate suggestions and comments into the design of the course in the following

years. Table II includes a summary of average scores for the course since 2012. Evaluations have indicated a clear level of satisfaction amongst each student class upon completion of the course. While enthusiasm for the course and points of strength vary from year to year, students express strong overall enthusiasm for all aspects of the course, with all areas averaging a score of 4.1 (out of 5) or greater (Table 2). On average, the highest scores are obtained for helpfulness of instructors, receiving an average score of 4.88.

Long-term Qualitative Impacts

In all, more than 300 trainees have participated in the course over its 33 year history. We assessed longer term impacts by 1) soliciting feedback from alumni in previous years of the course and 2) tracking of careers of former students.

We solicited feedback from alumni from 1996 to 2015 and asked how the course contributed to the individual's intellectual development, technical expertise, and publications, as well as impact on the field as a whole. In all, 85 alumni responded in full to the survey. The results of this survey reveal that the majority of students found the course to be helpful for their career (87%; Table 3). In addition, the vast majority reported that the course helped initiate new research directions (78%; Table 3) and was a highlight of their scientific career (95%). The high satisfaction with the course is indicative of substantive and long-lasting positive impact on career development.

The success of the course can also be measured by assessing the career trajectories of alumni. An exhaustive internet search of publically available information was conducted to identify the current positions of course graduates from 1983-2016 (Fig 1). We were able to confirm the career status of 287 former students of the course. This revealed that

280 64% are currently in academic faculty positions with 55% of identified course alumni in
281 tenure track positions. This number is remarkably high compared to recent estimates. In
282 the United States, an estimated 65% of graduate students move on to post-docs, and only
283 10-13% secure faculty positions [27]. In our course, a relatively small percentage of
284 graduates (29 students, 9%) obtained industry research positions, likely indicative of the
285 focus on basic science in *Drosophila* research and success in obtaining tenure track
286 positions. Importantly, alumni also showed a diverse set of non-research careers;
287 examples included scientific journal editors, teachers, and entrepreneurs. The long-term
288 impact on student success is indicative of a high return on investment, both in terms of
289 student time and scientific funding. Further, while difficult to quantify, it is likely that the
290 course's effectiveness extends beyond alumni as they were likely to share their training
291 with those in their local scientific communities. The fact that a large number of respondents
292 indicated that publications could be attributed to taking the course suggests that there was
293 indeed transfer of knowledge to local communities and that that knowledge was effectively
294 translated into research outputs. Indeed 90% of respondents confirmed that at least 2
295 publications could be attributed to taking the course (Table 4).
296
297 Beyond assisting the careers of individual students, the course is uniquely positioned to
298 provide training opportunities to those with limited access to research resources. While
299 many training opportunities, including National Institutes of Health NRSA fellowships,
300 strongly consider training environment, this course focuses on providing access to
301 students from diverse geographic and scientific backgrounds. The ability to recruit and
302 train students from diverse backgrounds has the potential to extend neuroscience training
303 to communities that are underrepresented in scientific funding. From 2008 until the
304 present, our course steadily increased numbers of students from URM backgrounds
305 (Table 1). The small class size inherently limits the number of URMs we can train. To

306 address this problem, in recent years (2015-present), special efforts have been made to
307 recruit students and lecturers who teach at URM serving institutions. This approach
308 provides the course with a way to extend Drosophila neuroscience into underserved
309 communities.
310
311 **Outlook for the future**
312 The CSHL *Drosophila* Neurobiology course has demonstrated remarkable success over
313 more than three decades. This likely reflects both a general effectiveness of the intensive
314 short summer course format for postgraduate researchers and the specific approaches
315 utilized by this course. In particular, the flexible curriculum, with rotating organizers,
316 instructors, and laboratories, have maintained cutting-edge research and techniques over
317 the duration of the course. Moving forward, we plan to continue this innovation by
318 investing in growing areas of research. For example, future iterations of the course are
319 likely to emphasize computational approaches to neuroscience, functional imaging and
320 quantitative tracking and analysis of animal behavior. In addition, we will increase the
321 emphasis on DIY approaches, such as use of 3D printing to construct laboratory
322 apparatus. Finally, we hope to leverage the success of this course to extend beyond the
323 reach of CSHL. For example, forming collaborations with faculty outside CSHL that extend
324 course laboratory modules into undergraduate curriculums will significantly broaden the
325 impact of the course. Indeed recent participants at the course have adapted CSHL
326 modules for use in undergraduate education and these modules are now published and
327 freely available [18,28]. Finally, generation of publically accessible protocol videos will
328 enhance the broader impact of this course. These points of emphasis, combined with
329 incorporating rapidly improving genetic technology in the fly, will allow this course to
330 remain current and innovative into the future.
331

Conclusions

Drosophila are uniquely suited to teach fundamental principles in neuroscience research. The amenability to laboratory manipulation and short generation time allow for implementation of cutting-edge genetic-technology to investigate development, physiology, and behavior in a short-course format. Our analysis reveals that the *Drosophila* Neurobiology Course has experienced remarkable success in terms of student satisfaction and career outcomes. The active emphasis on selecting students from diverse backgrounds promotes scientific access, gender equality, and success for underrepresented minorities.

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Works Cited

1. Kohwi, M. & Doe, C. Q. Temporal fate specification and neural progenitor competence during development. *Nat. Rev. Neurosci.* **14,** 823–38 (2013).
2. Evans, T. A. Embryonic axon guidance: insights from Drosophila and other insects. *Current Opinion in Insect Science* **18,** 11–16 (2016).
3. Frolov, R. V, Bagati, A., Casino, B. & Singh, S. Potassium channels in

358 Drosophila: historical breakthroughs, significance, and perspectives. *J.*
359 *Neurogenet.* **26,** 275–290 (2012).
360 4. Harris, K. P. & Littleton, J. T. Transmission, development, and plasticity of
361 synapses. *Genetics* **201,** 345–375 (2015).
362 5. Sokolowski, M. B. Drosophila: genetics meets behaviour. *Nat Rev Genet* **2,**
363 879–890 (2001).
364 6. Vosshall, L. B. Into the mind of a fly. *Nature* **450,** 193–197 (2007).
365 7. Bellen, H. J., Tong, C. & Tsuda, H. 100 years of Drosophila research and
366 its impact on vertebrate neuroscience: a history lesson for the future. *Nat.*
367 *Rev. Neurosci.* **11,** 514–22 (2010).
368 8. Kazama, H. & Wilson, R. I. Homeostatic matching and nonlinear
369 amplification at identified central synapses. *Neuron* **58,** 401–413 (2008).
370 9. Venken, K. J., Simpson, J. H. & Bellen, H. J. Genetic manipulation of
371 genes and cells in the nervous system of the fruit fly. *Neuron* **72,** 202–230
372 (2011).
373 10. Zwart, M. F. *et al.* Selective Inhibition Mediates the Sequential Recruitment
374 of Motor Pools. *Neuron* **91,** 615–628 (2015).
375 11. Aso, Y. *et al.* Mushroom body output neurons encode valence and guide
376 memory-based action selection in Drosophila. *Elife* **3,** e04580 (2014).
377 12. Seidner, G. *et al.* Identification of Neurons with a Privileged Role in Sleep
378 Homeostasis in Drosophila melanogaster. *Curr. Biol.* **25,** 2928–2938
379 (2015).
380 13. Vogelstein, J. T. *et al.* Discovery of brainwide neural-behavioral maps via

381 multiscale unsupervised structure learning. *Science (80-.).* **344,** 386–392
382 (2014).
383 14. Klein, M. *et al.* Sensory determinants of behavioral dynamics in Drosophila
384 thermotaxis. *Proc Natl Acad Sci U S A* **112,** E220-9 (2015).
385 15. Stavropoulos, N. & Young, M. W. Insomniac and cullin-3 regulate sleep
386 and wakefulness in drosophila. *Neuron* **72,** 964–976 (2011).
387 16. Seelig, J. D. & Jayaraman, V. Neural dynamics for landmark orientation
388 and angular path integration. *Nature* **521,** 186–191 (2015).
389 17. Pulver, S. R. & Griffith, L. C. Spike integration and cellular memory in a
390 rhythmic network from Na(+)/K(+) pump current dynamics. *Nat Neurosci*
391 **13,** 53–59 (2010).
392 18. Titlow, J. S., Johnson, B. R. & Pulver, S. R. Light Activated Escape
393 Circuits: A Behavior and Neurophysiology Lab Module using Drosophila
394 Optogenetics. *J Undergr. Neurosci Educ* **13,** A166-73 (2015).
395 19. Pulver, S. R., Hornstein, N. J., Land, B. L. & Johnson, B. R. Optogenetics
396 in the teaching laboratory: using channelrhodopsin-2 to study the neural
397 basis of behavior and synaptic physiology in Drosophila. *Adv Physiol Educ*
398 **35,** 82–91 (2011).
399 20. Pulver, S. R. *et al.* Why flies? Inexpensive public engagement exercises to
400 explain the value of basic biomedical research on Drosophila
401 melanogaster. *Adv Physiol Educ* **35,** 384–392 (2011).
402 21. Berni, J., Mudai, A. & Pulver, S. R. Using the warmth-gated ion channel
403 TRPA1 to study the neural basis of behavior in Drosophila. *J. Undergrad.*

Neurosci. Educ. **9,** A5–A14 (2010).

22. Pulver, S. R. & Berni, J. The fundamentals of flying: simple and inexpensive strategies for employing Drosophila genetics in neuroscience teaching laboratories. *J Undergr. Neurosci Educ* **11,** A139-48 (2012).

23. Fostier, M., Patel, S., Clarke, S. & Prokop, a. A Novel Electronic Assessment Strategy to Support Applied Drosophila Genetics Training on University Courses. *G3: Genes|Genomes|Genetics* **5,** 689–698 (2015).

24. Michels, B. *et al.* Pavlovian Conditioning of Larval Drosophila: An Illustrated, Multilingual, Hands-On Manual for Odor-Taste Associative Learning in Maggots. *Front. Behav. Neurosci.* **11,** 1–6 (2017).

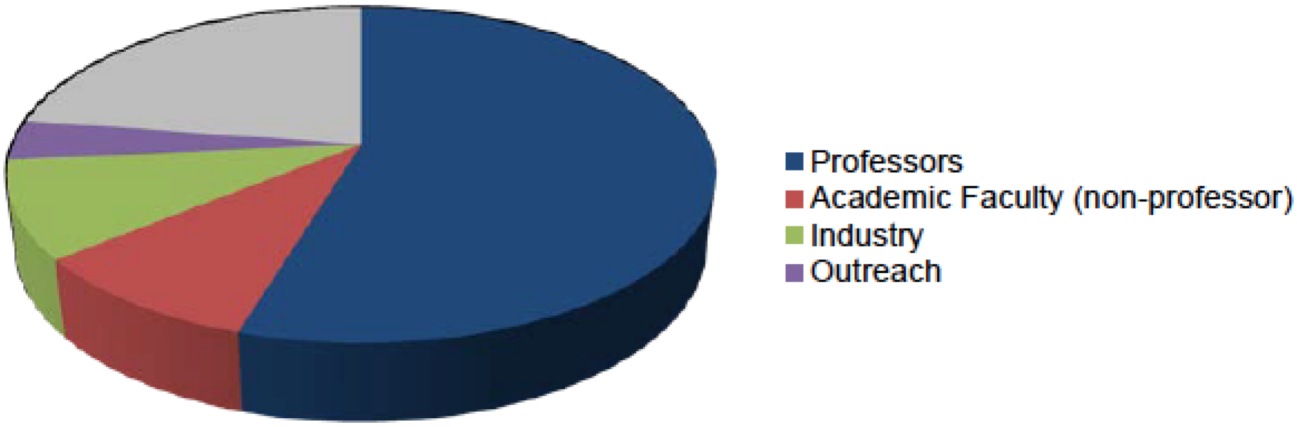
25. Baden, T. *et al.* Open Labware: 3-D Printing Your Own Lab Equipment. *PLoS Biol.* **13,** (2015).

26. Geissmann, Q. *et al.* Ethoscopes: An Open Platform For High-Throughput Ethomics. *bioRxiv* 113647 (2017). doi:10.1101/113647

27. Powell, K. The future of the postdoc. *Nature* **520,** 144–147 (2015).

28. McKellar Claire, E; Wyttenbach, Robert, A. A Protocol Demonstrating 60 Different Drosophila Behaviors in One Assay. *J. Undergrad. Neurosci. Educ.* **15,** A110–A116 (2017).

426 **Figure 1.**



427
428 **Figure 1. Current professional status of course graduates.**
429 In total**,** 55% of eligible course alumni received professor appointments, while 64%
430 hold academic appointments (including non-professor appointments). 9% of alumni
431 work in industry, 4% in outreach. Grey (23%) represents other professional
432 positions.
433
434
435

Table 1.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	**TOTAL**
Instructors	4	3	3	3	3	3	3	3	3	
Lecturers	29	21	17	21	14	18	19	22	26	
Assistants	5	5	6	7	4	4	3	3	10	
Applicants	52	34	24	23	43	42	32	32	36	**319**
Students	**11**	**12**	**12**	**11**	**12**	**12**	**12**	**12**	**12**	**106**
Grad Stud	7	6	7	8	8	10	9	6	6	**67**
Postdoc	2	3	4	3	3	2	3	4	5	**29**
PI/Sen Sci	2	3	1	-	1	-	-	2	1	**10**
Gender	6m/5f	5m/7f	6m/6f	5m/6f	6m/6f	5m/7f	7m/5f	6m/6f	5m/7f	**51m/55f**
US *(%)*	7*(64%)*	9 *(75%)*	6 *(50%)*	6 *(55%)*	9 *(75%)*	9 *(75%)*	8 *(67%)*	9 *(75%)*	9 *(75%)*	**72 *(68%)***
URM	1	1	1	1	1	2	na	2	3	**12 *(17%)***

Table 1: Makeup of course students, assistants and faculty from 2008-2016. The number instructors (Course organizers), lecturers, teaching assistants, applications, and students for each year from 2008-2016. The breakdown of students (bold) between grad student, postdoc, and PI/senior scientist, as well as gender. The percentage of students from the US. URM denotes US underrepresented minority.

Table 2.

	2012	2013	2014	2015	2016
In general, did the course meet your needs /expectations?	4.5	4.6	4.1	4.8	4.9
Were the lecture topics well chosen?	4.5	4.5	4.1	5.0	4.8
Was the level of the lectures appropriate?	4.3	4.7	4.5	4.8	4.8
Were the presentations clear?	4.2	4.5	4.1	4.5	4.6
Were the instructors helpful?	4.9	4.9	4.6	5.0	5.0
Was the selection of lab exercises appropriate?	4.1	4.5	3.6	4.7	4.8
Was there sufficient/too much supervision of the lab?	4.3	4.5	4.2	4.5	4.8
Were the labs well enough equipped?	3.9	4.4	4.2	4.3	4.8
What was the utility and quality of the written protocols?	3.8	4.4	3.4	4.3	4.5
How was the course work load?	4.5	4.3	4.4	4.4	4.8

Table 3: Student course evaluations from 2012-2016. Average scores from course evaluations over a five-year period. Scale: 1-Poor->5-Excellent.

Table 3.

	Strongly Agree	Agree	Neutral	Disagree	Stro Disa
The course helped me achieve my next career transition.	41	31	11	0	1
The course had a positive impact on my scientific career as a whole.	71	13	1	0	0
The course helped me initiate a new research direction.	39	29	15	1	1
The course taught me new techniques that were subsequently applicable to my research	56	24	2	0	2
The course was a highlight in my scientific career.	56	24	2	0	2
The course has a positive impact on the broader biological research community.	62	19	3	1	0
	YES	**NO**			
Do you still work in this scientific area?	70	12			
	10+	**~7**	**~4**	**~2**	**0**
Number of research publications that could be attributed to taking this course?	4	10	14	49	7
	3+	**3**	**2**	**1**	**0**
Number of patents that could be attributed to taking this course?	1	0	1	3	72

Table 3. Long-term impact assessment of students from 1996-2015. Previous students were contacted and asked about the impact the course had on the career over the summer of 2016. The number of responses for the 85 recipients for each category are listed.