TURNING POINT Publishing when your research won't reproduce **p.129**

GENDER BIAS Attitudes will be difficult to change on evidence alone **p.129**

DATA NEEDED Where PhDs go after graduation **p.129**

WAVEBREAKMEDIA/SHUTTERSTOCK

Fresh perspective

Undergraduate researchers can boost a lab's energy and work, but need help to flourish.

BY PAUL SMAGLIK

Alan Berkowitz was taken aback when a colleague told him that undergraduate research is an oxymoron. Berkowitz, head of education at the Cary Institute of Ecosystem Studies in Millbrook, New York, had reason to be surprised. Since 1988, he has been running an undergraduate research programme at Cary, and he recruits up to a dozen students a year for the institute's 12-week summer session. He says that undergraduates are much more than cheap labour and can contribute to further insight. In training them, he says, he has seen his own scientific thinking sharpen.

Had Tracy Johnson not gained research experience as an undergraduate, she says, she probably would not have done a science PhD. "As with many students who love science, I'd only considered medical school," says Johnson, now a molecular biologist at the University of California, Los Angeles. The experience changed her career trajectory. "When I was in the lab, it was like the world opened up. I understood what the process was. I learned you could create new knowledge. If you had the right intellectual tools, you could ask and answer questions." Her adviser helped her to realize that she could contribute to science, even at this early point in her career. "It was a wonderful experience because he was a terrific mentor, and he created a research environment that was rigorous but fun," she says. "The postdocs and graduate students in that lab seemed to have fun working together and doing great science. That experience set the bar for what I wanted my own research lab to be like."

Whereas the benefits of undergraduate research for the student might seem obvious, some — like Berkowitz's colleague — wonder why a principal investigator (PI) would ever want to staff their lab with inexperienced people who have busy coursework schedules that make it hard to attend regular meetings or get into a work rhythm. Rotating undergraduates into and out of a lab every summer or semester means that PIs must find projects that do not require a long-term commitment. And, of course, undergraduates will have a steep learning curve just to master the basic language of the lab, let alone its protocols and techniques.

A PI who decides to bring in undergraduates will need to plan for their inexperience and time constraints. Experiments cannot be left unattended with the assumption that an undergraduate will know what to do. It may be necessary, say veteran lab heads who have hosted many undergraduates, to be more patient than with older trainees, and to spend more time in the lab rather than analysing data or writing grant applications. But the pay-offs can be significant. Some of those benefits include providing mentoring opportunities and soft-skill building for graduate students and postdocs. And sometimes an undergraduate's unbiased opinion can benefit a research project. At other times, simply having more hands in a lab can speed up the work. Furthermore, a PI and other lab members can help to drive a young student's career choice, just as they did with Johnson's.

PROJECT MANAGEMENT

When undergraduates form part of a lab team, it is important to come up with experiments that have a definitive end point and can be divided into small, manageable blocks, says David Asai, who runs the undergraduate research programme at the Howard Hughes Medical Institute in Chevy Chase, Maryland, which places students with investigators around the nation. "Undergrads are very busy. They have classes they have to take. They are involved in lots of other things that are important," he says.

Susan Singer, director of the US National Science Foundation's Research Experience for Undergraduates programme, says that she worked with undergraduates for some 30 years in her developmental-biology lab. She agrees that it is crucial to structure research projects to align with students' availability and experience. During one gene-expression experiment, for example, she parcelled her students into groups, each of which looked at a different gene. Every four hours, different students in each group would collect plant tissue samples and RNA, ensuring that no person was solely responsible for any one data point, and no important information ever went missing. "You have to build in redundancies, checks and balances," she says. ▶

Jackie Tanaka, who leads an undergraduate research programme at Temple University in Philadelphia, Pennsylvania, finds that investing more time up front pays off. Research projects typically require a lot of repetitive tasks that could elicit complaints of boredom if the students do not understand why the jobs need to be done. "Students have to be trained in the need for care and reproducibility," she says. "They don't necessarily realize the importance of what they are doing." Working with undergraduates is also likely to require tact and diplomacy, she says. They sometimes have difficulty accepting feedback, especially when it is constructive rather than positive. "It takes patience," she says.

However, undergraduates often have greater patience for repetitive tasks than do more-senior scientists, says Ritwick Sawarkar, a group leader at the Max Planck Institute of Immunobiology and Epigenetics in Freiberg, Germany. "The younger people are much more cheerful and bring in so much excitement to the lab," he says. "Every DNA gel brings them joy."

VALUABLE CONTRIBUTIONS

Sometimes, that naivety even translates into scientific success. During one meeting, Sawarkar's group was stuck trying to find a way to inhibit a protein in a cell's nucleus. An undergraduate with a chemistry background offered a suggestion that the group had never considered. Sure enough, when the researchers checked the chemistry literature, they found that her suggestion was a viable method that they eventually used. "She opened our eyes to look into an area we wouldn't have normally considered," says Sawarkar.

Getting students comfortable enough to pitch in takes effort, however. Catherine Drennan, a structural biologist at the Massachusetts Institute of Technology in Cambridge, says that she starts by having her postdocs and graduate students teach her undergraduates basic protein-crystallization techniques. She then assigns the undergraduates proteins to crystallize. Eventually, the students pick their own proteins and crystallization methods. "My overall goal is to train them to do basic stuff," she says. "Once they learn the ropes they can carve out their own puzzle."

Her lab lends itself well to undergraduate research because protein crystallization requires short efforts over a long period. Students can put a protein into solution, leave it for a few hours, perhaps while attending a class, then return to check on it. They then tweak the solution by changing the concentration, temperature and pH level, among other factors, until they get the combination right. "Sometimes the first thing you try works and sometimes you have to try hundreds," Drennan says. Having undergraduates take on this step frees her graduate students and postdocs to characterize the crystallized proteins. She has also seen undergraduates succeed where older trainees have failed, thanks to their persistence. "They are willing to try to just problem-solve," she says. "They can help to rule out a whole bunch of things that don't work."

"This is an essential skill set that you cannot sit in a classroom and learn."

Martin McLaughlin loves working in Drennan's lab, where he started in his first year at university. His experience there has given him the confidence to pursue a scientific career after he graduates this year. "It's a very close-knit environment," he says. "You can walk around the lab and ask anyone a question. We take care of each other." First-year student Devany West, who joined the lab just last month, says that she especially values the chance to find out what it is like to be a researcher while the stakes are lower because neither her degree nor career depend on the work. "You're being nurtured," she says. "There's an element of being intimidated. But you are not expected to be perfect. You're expected to mess up."

Undergraduates in a lab can also help PIs and older trainees to learn how to promote their own research, says Berkowitz. Having to break down research problems and explain them to an undergraduate forces the senior researcher to think about how best to develop hypotheses and design the most effective experiments to test them, he says.

In addition to the pay-off for the PI and senior lab members, there is altruistic value to hosting undergraduates. For one thing, it provides an early opportunity for students to discover that they hate the bench, before committing to doctoral programmes and postdoctoral research. "They work in the lab and confirm they love science — but they find they don't like lab work," says Singer. She has hosted undergraduates who have become researchers and those who have taken other paths, such as science journalism or lab management. "Both are successful outcomes," she says.

Micky Einstein, a doctoral student in neuroscience at the University of California, Los Angeles, credits his experience as an undergraduate researcher for giving him early insight into lab management. For instance, he knows that undergraduates' motivations for joining a lab vary. Therefore, he can help to weed out applicants who want only to add a line to their CV and are not that interested in the actual research experience.

Ramesh Pillai, a group leader at the European Molecular Biology Laboratory (EMBL) in Grenoble, France, says that managing undergraduates provides postdocs and graduate students with invaluable experience. "This is an essential skill set that you cannot sit in a classroom and learn."

Lionel Newton benefited from postdoc and graduate mentors as an undergraduate at the EMBL in Heidelberg in 2008. Now, as a postdoc and manager there himself, he knows the importance of finding out what undergraduates already know, both practically and theoretically. They can become annoyed if a mentor repeatedly explains things they already know, but can equally get stressed if the supervisor simply hands them a piece of equipment and disappears, Newton says. "It's only through communications in the early days that you can avoid these kinds of frustrations," he says.

With good management and communication, hosting undergraduates may well be "transformative" for both them and their mentors, says Johnson. That is a much more apt way to describe undergraduate research than "oxymoron". ■

LAURA DOUGHTY.

Catherine Drennan (left) is keen to have undergraduates help with the research in her lab.

Paul Smaglik *is a freelance writer in Milwaukee, Wisconsin.*

CORRECTION

The Careers Feature 'Speak up for science' (*Nature* **517,** 231–233; 2015) neglected to include the UK-based charity Sense About Science as an organizer of the John Maddox Prize.