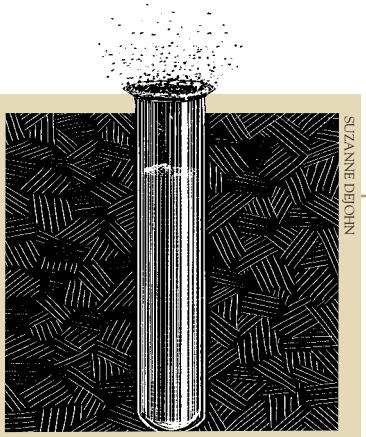
Critical thinkers

By Constance Brinckerhoff, Ph.D.



SUZANNE DEGAN

This fall, 48 new Ph.D. students in the biomedical sciences arrived on the Dartmouth campus, joining more than 140 already at DMS. Although most are from the U.S., they also came from Israel, Taiwan, Canada, India, Eastern Europe, Australia, and China. They'll spend approximately five years at Dartmouth, but unlike students in the M.D. program, they do not move *en masse* from one class to another or cram for biweekly quizzes. Rather, they are squirreled away in laboratories all across campus. So just who are they and what do they do?

Students are transformed from naive and enthusiastic neophytes into rigorous, sophisticated (but still enthusiastic) scientists.

Selected each year from an applicant pool of nearly 500, they come to Dartmouth with excellent undergraduate credentials to be trained in research in the life sciences: Molecular and Cellular Biology; Pharmacology and Toxicology; Immunology; Molecular Pathogenesis; and Physiology. They want to become scientists and conduct critical studies that will ultimately benefit the health of people across the country and around the world.

Expression: Training for the Ph.D. is different from training for the M.D. Graduate programs emphasize individual learning experiences. Doctoral students work at laboratory benches, carrying out experiments that are often designed to answer small questions like "What concentration of a drug is needed to change the expression of a single gene?" Students use the results of early experiments to design their next ones, which answer more questions, until eventually a broader story is told. Each "story" is incorporated into papers that are submitted for peer review and publication, and then into a thesis that embodies all of that student's research.

During the five or more years it takes to complete such a program, students are transformed from somewhat naive and enthusiastic neophytes into rigorous, sophisticated (but still enthusiastic) young scientists. In the first year, they take courses—similar to those that medical students take—that introduce basic concepts in science and research and that build a foundation for analytical thinking. Interestingly, a large part of this didactic information may be outdated by the time students earn their Ph.D.'s. So we also equip students with lifelong learning skills.

Thesis: Along with coursework, students do three 10- to 12-week research rotations in different labs, where they learn about the research that goes on, both conceptually and technically. Then each student selects a thesis lab where he or she will undertake an original research project and write a thesis. The student also prepares for the qualifying exam, an exercise that involves choosing a scientific topic, reading the literature on it, and developing a research proposal to be presented to and critiqued by faculty on the qualifying committee. The process is difficult and requires the student to think carefully about how an experiment is developed, what the outcomes may be, and what might be the next steps. Often, committee members raise issues and ask questions that the student might not have considered. The student thus learns how to think about problems from different perspectives and strengthens his or her ability to think creatively yet critically. Once students pass the qualifying exam, they are considered "qualified" to concentrate full time on their research for the Ph.D.

But clearing that hurdle is only the first of many challenges. Very few experiments give the expected results, so the student and mentor may question the original hypothesis upon which the thesis goals are based. In addition, technical difficulties may emerge: reagents may not work as anticipated, cells might not grow as expected, and so on. Thus the early phase of a research project can be a discouraging period in which there may be little or no progress. Time is passing, with nothing to show for it. Now students learn the true meaning of research: persevering in the face of difficulty, thinking in imaginative ways about the problem, and reading the literature in order to integrate the work of others with their own. Eventually, there is a "eureka moment," when suddenly there's a breakthrough. They *do* understand the experimental system. They *do* get meaningful results.

Prize: As the fourth year rolls around, students have nearly mastered their thesis topics. During the next nine to 12 months, they write papers, prepare their theses, give seminars, and defend their work before a faculty committee. After a successful defense, congratulations are in order—the degree won't be officially awarded until the next commencement, but the prize has been won!

Some graduates continue their training as postdoctoral fellows at other institutions. Many become faculty at teaching and research institutions. Others join pharmaceutical or biotech companies. A few earn additional degrees, such as in law or business, and use their combined expertise to forge novel career paths. Ph.D. training prepares people to carry out rigorous studies at the cutting edge of science; develops their skills for critical thinking; and builds in them an understanding of both the power and the limitations inherent in the experimental method. DMS accomplishes this training exceedingly well partly because of the high quality of the students we recruit and partly because of the caliber of faculty who serve as mentors.

Ph.D. students bring imagination, energy, and intellectual vigor to the labs where they train as well as to the entire campus. Their curiosity, their excitement about science, and their commitment to their work are vital to the academic life of the institution. ■

"Grand Rounds" covers a topic of interest to the Dartmouth medical faculty. Constance Brinckerhoff is the Nathan Smith Professor of Medicine and of Biochemistry, as well as Dartmouth Medical School's associate dean for science education.