Strength in diversity: a cross-disciplinary approach to graduate training in chemical biology

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Chemical biology graduate programs that are jointly organized by chemistry and life science departments can offer a stimulating 'bicultural' training environment for students from diverse backgrounds. However, communication, flexibility and responsiveness are crucial for effectively structuring such programs.

As an undergraduate considering a research career in the 1970s, I was torn between the relatively clear, well-posed questions that were being addressed by chemists and the more poorly defined yet fascinating problems that confronted researchers in the life sciences. Although subsequent evolution of both fields has done much to narrow this divide, it still takes a bold graduate student to seek a sophisticated understanding of both the capabilities of modern chemistry and the complexities of current biological research. The emergence of chemical biology as a distinct field challenges us to provide such cross-disciplinary training to students in a systematic, effective manner.

The chemical biology program at McGill University (http://www.mcgill.ca/biochemistry/chemicalbiology/) was established in 2002, as a joint initiative between the Department of Biochemistry, the Department of Chemistry and the Department of Pharmacology and Therapeutics. It currently comprises roughly 30 graduate students, 10 postdoctoral fellows and 30 faculty mentors, with each group divided almost evenly between the Department of Chemistry and the life science departments. Most of our trainees aim to pursue careers in academic institutions or in the pharmaceutical or biotechnology industries, which are well represented by both established and start-up companies in the Montréal area. Though our program continues to evolve, three elements have proven to be of central importance: fostering a strong appreciation of chemical biology as a distinct and unifying discipline, maximizing communication of ideas and perspectives between participants trained in the life sciences and those with chemical backgrounds, and maintaining a flexible, critical and responsive approach to ensure that the program fulfills both our training objectives and the needs of our graduate and postdoctoral trainees.

The main campus of McGill University is in downtown Montréal at the foot of Mount Royal.

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Boundary conditions

We chose to establish the chemical biology program within the framework of existing departments at McGill for both practical and pedagogic reasons. At McGill, as at many other institutions, creating an

The Department of Biochemistry and the Department of Pharmacology and Therapeutics are located in the McIntyre Medical Building.

interdepartmental graduate program (formally designated as an Interdepartmental Graduate Option) is a much more rapid and flexible (and less resource-intensive) process than establishing a new academic unit. Also, building a program using faculty mentors based in both traditional chemistry and life science departments helps to ensure that students receive truly cross-disciplinary training, including a clear understanding of the perspectives of both chemists and biologists that can serve them well in their careers. Students in our program register for one of the three participating departments and for the Chemical Biology Option, and through their graduate work they fulfill the degree requirements of both. A key priority (and challenge) for the program is to ensure that students from all the participating departments achieve a shared and well-rounded understanding of the philosophy, practice and distinctive nature of the discipline of chemical biology.

Governance and organization of the program is carried out by a program committee consisting of six faculty members appointed by the chairs of the participating departments. The committee is chaired by a program coordinator who also administers the program on a day-to-day basis, working with appropriate departmental personnel. The committee reports to a program director, who oversees the financial aspects of the program and reviews broad issues of policy, and to an external advisory board composed of senior researchers from other academic institutions and from industry, which meets annually to evaluate the program. These arrangements provide a good balance of on-the-ground realism and big-picture vision for guiding the development of the program.

Financial support for our program is provided by the Canadian Institutes of Health Research, through its Strategic Training Initiative (http://www.cihr-irsc.gc.ca/e/22174.html), and by the Faculties of Medicine and Science and the Graduate and Postdoctoral Studies Office of McGill University. The funds are used to provide competitively awarded scholarships for students in the early years of their programs, conference travel awards to more senior graduate students, and support for an extensive program of workshops and seminars (with additional contributions from local industry). The US National Institutes of Health provides support for similar programs at American institutions through its Chemistry-Biology Interface Training Program, established in 1992 (http://grants.nih.gov/grants/guide/pa-files/PA-92-063.html).

Creating a culture

It is a mistake either to exaggerate or to ignore the cultural differences that can exist between students (and mentors) trained in chemistry and those trained in the life sciences. As cellular and organismal biology becomes ever more molecular, undergraduate students in the life sciences acquire an increasingly broad knowledge of fields such as bioorganic, biophysical and bioanalytical chemistry. Similarly, undergraduate students in chemistry are exposed to an ever wider range of biological problems as these become amenable to rigorous exploration using chemical approaches. It is nonetheless important to recognize that graduate training in chemical biology entails integrating both life science and chemistry students into a new culture that may at first seem foreign to both groups. For example, the marriage of discovery-oriented technologies such as high-throughput chemical screens with more 'precise', reductionist approaches such as those of structural biology or organic synthesis is commonplace in chemical biology, yet it requires of its practitioners a special and decidedly nontraditional mix of talents and interests.

Our program seeks to produce graduates who can work in a productive, innovative manner within this new culture but who can also interact effectively with individuals trained more traditionally in chemistry or in the life sciences alone. Fulfilling these objectives does not require that students receive equal training in both parent disciplines (which could deprive graduates of the depth of training in particular skills that may be crucial for their future careers). Instead, we seek to ensure that our graduates will genuinely understand the perspectives of colleagues trained in either parent discipline, and will have the skills and knowledge to be creative and proactive in identifying and developing novel means to combine the powerful tools of chemistry and biology to address key biological problems.

How can we fulfill these objectives for students with diverse undergraduate backgrounds? One essential priority is, of course, designing a curriculum that ensures that all students acquire a common formal training in the key elements and the philosophy of the discipline. Because students enrolled in the chemical biology program must also fulfill the

BOX 1 REPRESENTATIVE CORE LECTURE COURSES FROM MCGILL'S CHEMICAL BIOLOGY PROGRAM

One course chosen from:

- Advanced Bioorganic Chemistry
- Drug Design and Development 1

plus two additional courses from the above list and/or the following:

- Advanced Organic Synthesis
- Advanced NMR Spectroscopy
- Bioanalytical Separation Methods
- Bioinorganic Chemistry
- Drug Design 2: Computational Methods, Combinatorial and Parallel Synthesis
- Genomics and Gene Expression
- Structural Biology and Proteomics
- Techniques in Molecular Genetics
- Topics in Pharmacology

BOX 2 TOPICS OF SELECTED MCGILL CHEMICAL BIOLOGY WORKSHOPS

Chemical Biology of RNAs and ssDNAs
Bioinformatics Methods in Genomics
New Directions in Computational Chemistry
Creation, Evaluation and Management of Chemical Libraries
New Frontiers in Structural and Chemical Biology
Automated Methodologies in Structural and Chemical Biology
Bioethics and Scientific Integrity
Career Choices in Chemistry and Biomedicine

standard degree requirements of their 'home' departments, the program requires a relatively small number of formal lecture courses (**Box 1**) that nonetheless provide students from diverse backgrounds with a common core of knowledge on which to base their further training in the discipline. Our Drug Design and Development 1 course, for example, is co-organized and team taught by members of the Department of Chemistry and the Department of Pharmacology and Therapeutics, with additional contributions by lecturers from local pharmaceutical companies.

Students in the program also enroll in a series of 'Seminars in Chemical Biology' courses, mainly featuring presentations by researchers from other institutions. These seminars have always been of high quality, and they convey to students the breadth and excitement of work at the cutting edge of the field. However, they can also be very challenging to organize in a way that allows all students, regardless of their diverse backgrounds, to appreciate and profit from the material presented. To complement the standard discussion meetings between students and visiting speakers, in response to students' feedback we have become steadily more active both in distributing preparatory materials (such as biographies and readings) in advance of seminars and in ensuring that speakers understand the special nature of our program and our student population. Also, in conjunction with each seminar we are now scheduling a new feature, proposed by our students, in which trainees meet on their own to discuss the seminar topic, thereby allowing them to share background knowledge and insights reflecting their different perspectives.

A valuable and well-received feature of our training program is a series of full-day workshops held twice a year. These workshops focus on important emerging technologies and research directions within the field, or occasionally on more general professional issues of importance to workers in the discipline (**Box 2**). Many workshop speakers are invited from other institutions, and ample opportunity is provided for students to pursue informal discussions with them during their visits. Workshops often combine 'card-carrying' chemical biologists with speakers from more traditional backgrounds, who provide complementary perspectives on important research areas and methodologies. For example, one workshop on chemical libraries included presentations describing not only high-throughput screening and cheminformatics methods but also new organic-synthetic strategies for preparing specific types of libraries and a case history of the development and assessment of a drug by a pharmaceutical company. Workshops are open to the wider university community, which enhances communication and program visibility with other research groups and departments. A recent workshop, for instance, featured presentations on aptamers, micro-RNAs and small-molecule modulators of protein translation and attracted nearly 150 researchers from the greater Montréal area.

Fostering communication

A key objective of the program is to maximize opportunities for students with chemistry and life science backgrounds to share and appreciate their sometimes distinct perspectives on the field of chemical biology. Seminar discussion meetings, workshops and an annual research symposium at which students present their work to other students and faculty mentors are some of the means we use to promote this objective. Journal clubs, and meetings in which students present their research work to each other in an informal atmosphere, are also potentially very useful in this regard. However, in a cross-disciplinary program with a diverse student population, it is particularly important to regularly review the format and effectiveness of such activities and to be proactive in adapting them to students' needs and aptitudes. Questions about the formats of research symposia and discussion groups, the selection of discussion topics and the degree to which faculty members should participate in some of these activities cannot be addressed in a purely top-down manner and must be periodically re-examined. We solicit written evaluations and suggestions annually from our students and find much to work with (and on) in each year's responses. The format of our seminar program, for example, has steadily evolved in response to students' feedback, as discussed above.

Promoting cross-disciplinary research

The research component of a chemical biology program must promote a strong understanding of the diverse methodologies and the cross-disciplinary nature of the discipline. Students applying to our program (unlike those applying to our standard graduate programs) must prepare a formal description of their proposed research that is reviewed by the program committee to ensure that it will provide high-quality and truly cross-disciplinary training in the philosophy and methodologies of the field. The range of proposals we receive is quite broad, in some cases prompting discussions about where the limits of chemical biology lie—a question that continues to occupy the field as a whole. Perhaps surprisingly, in such cases

The Otto Maass Building houses the Department of Chemistry.

the committee often finds a large degree of consensus.

As a further measure to ensure that students receive genuinely cross-disciplinary training through their research, students in the program meet regularly with research advisory committees that include members from both the chemistry and the life science departments. We also actively encourage both *ad hoc* and formal co-supervision of student projects by mentors from the two parent disciplines. Meaningful, productive collaborations of this nature cannot of course be ordained; they can only arise from a strong network of communication among researchers and a climate that promotes collaborative research. Seminars, workshops and discussion groups can thus be as valuable for promoting interactions among faculty mentors as they are for fostering communication among trainees.

Conclusion

The emergence of new disciplines at the interfaces between older ones is a long-standing and exciting aspect of science. An effective training program in chemical biology must produce graduates who have a distinct sense of intellectual identity yet can work effectively with researchers that are more conventionally trained either in chemistry or in the life sciences alone. A training program in which faculty mentors based in chemistry and life science departments work together under a comparatively lightweight administrative superstructure offers an effective and relatively inexpensive means to achieve this objective. Moreover, by promoting constant intermixing of individuals trained in the cultures of chemistry and biology, such a program allows students to be participants in the very type of stimulating, creative ferment that drives the field of chemical biology itself.