Educating the Microbiologist of the Future:
The Role of Summer Courses
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by Ann Reid

This report is based on a colloquium convened by the American Academy of Microbiology on January 14-16, 2011 in San Francisco, CA.

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Executive Summary

Each summer, scores of graduate students, post-doctoral fellows, mid-career faculty, and seasoned researchers gather for “full-immersion” courses presenting microbiology as it is actually practiced. Some of the courses are as short as a week, while others last a month or even six weeks, and the particular topics on which they focus vary widely, reflecting the remarkable breadth of microbiology. What all the courses have in common, however, is their outstanding track record of changing the lives of their participants, and the ripple effect of those changed lives on the progress of the microbial sciences. However, it is difficult to measure the impact of such courses, and no such effort has been systematically undertaken. Nevertheless, it is clear that leading researchers continue to devote substantial time to organizing and teaching such courses, sponsors continue to invest in them, and their alumni not only go on to successful research careers but also return to teach at the courses. All of these facts are a strong indication that the value of advanced summer courses is considerable. Given the significant resources required, and in a time of tight budgets, it is worth considering how these courses can make the best possible use of limited research funds.

The group agreed on the following five take-home messages:

- **ADVANCED SUMMER COURSES ARE UNIQUELY VALUABLE**
  The courses serve a unique function as capstone courses for the professional development of early career researchers and as critical opportunities for mid and late career scientists who want to explore new directions in their research.

- **ADVANCED SUMMER COURSES ARE RESOURCE-INTENSIVE BY NATURE**
  These courses are extremely labor and resource intensive and the capacity for offering them is limited in many respects.

- **SOME CHALLENGES ARE COMMON TO ALL THE COURSES**
  Faculty support, evaluation, alumni follow-up, outreach, faculty recruitment, and fund-raising are challenges faced by all of the courses.
- **IMPACT CAN BE BROADENED BY MODULARIZATION**
  New technologies offer opportunities to broaden the courses’ impact.

- **THERE ARE OPPORTUNITIES FOR SYNERGY AND COOPERATION**
  The courses have a number of needs in common. It would be worthwhile to consider developing a systematic means of meeting those needs, and sharing information, ideas and best practices among the various courses.

Accordingly, the group proposed the following recommendations:

- **CONTINUE SUPPORT FOR SUCH COURSES**

- **ESTABLISH A COMMON PLATFORM TO MEET COMMON NEEDS**

- **CONVENE AN ADVISORY GROUP TO KEEP TRACK OF THE MIX OF COURSES OFFERED, IDENTIFY GAPS, AND FACILITATE THE ESTABLISHMENT OF NEW COURSES**

- **INSTITUTE AN ANNUAL MEETING OF COURSE ORGANIZERS**

- **TAKE ADVANTAGE OF ADVANCES IN TECHNOLOGY TO MAKE COURSE CONTENT AVAILABLE TO MORE STUDENTS**
Introduction

There is no better introduction to the topic of this report than testimonials from the students whose lives have been profoundly affected by attending a full-immersion summer course in microbiology. Here are just a few examples:

Those six weeks have been one of the most exciting and enjoyable times of my life...A small town with a magnificent library, where you meet remarkable scientists, where you have a lab to work in all day long, where you can stop working only to go and get your daily meals, and nothing to distract you from science, is the closest definition to heaven on earth for me.

It seemed as though we (meaning the 20 students from 16 institutions and 9 countries) woke up for morning lectures and then essentially lived in the lab for 6 solid weeks.

The other students probably taught me as much as the instructors did, and the whole atmosphere of the course...seemed to foster intellectual stimulation.

My lab partner...and I are still collaborating after 10 years.

The course was one avenue by which a mid-career scientist, such as myself, could relatively quickly catch-up on some of the latest insights and advances.

One of the things I got out of this class is that now I am able to better involve undergraduate students doing research in my lab... There is no doubt that [the faculty] are great scientists. Yet what makes them different than other scientists is that they are caring and dedicated teachers. They made
me believe that I can be a good scientist in a liberal arts college where support (as well as student talents) is limited.

The course...helped me develop important skills for working in interdisciplinary groups and encouraged collaborations and relationships with scientists from all over the world that are still strong today.

At the request of the Agouron Institute and the Gordon and Betty Moore Foundation, the American Academy of Microbiology convened a group of distinguished microbiologists to discuss advanced microbiology summer courses. On January 14-16, 2011 the group met in San Francisco, CA to assess the current state of these courses and to discuss how they might be improved, evaluated, and sustained. This report is a summary of the group’s discussions.

The report makes specific recommendations that should be applicable to a large number and wide diversity of full-immersion summer courses in the microbial sciences, from those with a heavy laboratory component to those that are predominantly lecture-based. Because of the group’s composition the report draws most of its examples from a more limited set of courses including seven courses that have intense laboratory components and two that are predominantly lecture-based with some hands-on computational biology components.

- **Laboratory-Based Courses**
  - Marine Biological Laboratory Microbial Diversity Summer Course (Woods Hole, MA)
  - Marine Biological Laboratory Molecular Mycology Course (Woods Hole, MA)
  - Hawai'i Summer Course on Microbial Oceanography
  - Hopkins Microbiology Course
  - Bermuda Institute of Ocean Sciences (BIOS) Microbial Oceanography Summer Course
  - University of Southern California Geobiology Summer Course
  - Cold Spring Harbor Advanced Bacterial Genetics

- **Lecture-Based Courses**
  - EMBO-FEBS Host-Microbes Interactions, Spetses, Greece
  - John Innes/Rudjer Bošković Summer Schools in Applied Molecular Microbiology

What all of these courses have in common is small size, fast-paced coverage of the latest results and concepts by highly experienced researchers (often the leaders of the field), exposure to the most advanced laboratory practices, tools and techniques, and original scientific inquiry. These are not the only such courses offered, but because participants at the colloquium had direct experience with them, they formed the basis of the discussions.
There are many other summer courses in microbiology that target different audiences—high school students and teachers, undergraduates, or university teachers—but the focus of this report is on the advanced and intensive summer courses aimed at graduate students and junior faculty who intend to pursue careers predominantly as academic researchers.

**During the colloquium, small groups tackled each of the following topic areas and questions:**

- **Improving the Courses:**
  - How can these courses be made even better?
  - What are the opportunities for:
    - Integration and synergy among existing courses?
    - Development and dissemination of best practices?
    - Integration of new technologies to improve learning, teaching, communication, and accessibility?

- **Expanding the impact of the courses:**
  - How can the impact of the courses be maximized?
  - How can the courses be encouraged to evolve, incorporate technology, and integrate new fields and approaches?
  - How can they be made available to more students?
  - How can the faculty be better supported and how can their participation in summer courses enrich their home institutions?
  - Can the summer courses be replicated more widely?

- **Evaluating the Courses:**
  - What makes the courses work?
  - What do we want students to get out of them?
  - What do we want faculty to accomplish and what do we want faculty to gain by participating in these courses?
  - How can we measure whether those goals are being achieved?

- **Making the Courses Sustainable:**
  - How do we demonstrate value to faculty, students, university administrators, and potential funders?
  - How do we keep the courses fresh?
  - How do we balance tradition and innovation?
  - What is the optimal use of resources – more courses, training grants to replicate the courses, or some other model?
  - How can funders make the biggest impact? What are some ways to increase 'bang for the buck'?
  - How can it be made more attractive for faculty to teach in these courses?

The report that follows synthesizes the small group and plenary discussions and includes a set of recommendations that the participants agree would help preserve and extend the many benefits of these courses.
Advanced summer courses are uniquely valuable

It is no secret that it takes a lot of talent and drive to succeed in academic research. Only a small fraction of the students who enter graduate programs in the biological sciences eventually become independent researchers. Full-immersion summer courses like the ones described in this report are specifically targeted to this particular group. The courses provide these students with a realistic research experience, and a host of additional benefits. At the same time, these courses contribute to the world’s scientific enterprise in general because they serve as crucial tools for recruiting outstanding students into new and emerging fields. The courses are training grounds for future leaders of these new fields and offer networking opportunities for students and teachers alike.

Full immersion into science as it is really practiced

During the marine microbiology courses in Hawaii and Bermuda, students spend time both in the lab and at sea. For oceanographers who are considering working on microbes, this is an opportunity for a crash course in biology and an experience of how microbiology is currently practiced. For microbiologists interested in the ocean environment, an intensive exposure to the field of oceanography is augmented by the opportunity to see whether life on a boat is really for them. For both groups, the courses broaden horizons, teach new skills and concepts, give a first-hand exposure to interdisciplinary teamwork, and allow the students to teach and learn from each other. Even for those courses that are not held in an entirely new environment, most of the topics covered are interdisciplinary and organizers deliberately choose student participants from different backgrounds. Thus, the experience of a small group of people with varied levels and types of expertise, immersing themselves in a scientific project as a team, is common to all of these courses. Also, the courses waste no time bringing students quickly to the cutting edge of the science. The pace is rapid and the work load demanding. One course instructor said that “if students thought they were already working hard as a scientist, this is when they find out what hard work really looks like.” Another participant noted that the intense pace is “efficient—you can get more done in a few weeks than in a year or two in a traditional university atmosphere.”
Intensive introduction to emerging fields or the cutting edge of established ones

The courses discussed at the colloquium fall into two broad categories. One category is made up of courses that aim to launch new fields at the intersection of existing ones. Such is the case of the geobiology and microbial oceanography courses discussed at the colloquium. The goals of these courses go beyond what happens during the course itself. Such courses also aim to recruit and train a cohort of scientists who will carry the field forward (Box 1).

Box 1: A multi-generational science network

Many of the participants in the colloquium remarked on how microbiology summer courses often change students’ interests and career trajectories. Two of the participants spoke from personal experience:

Diane Newman attended both the Microbial Diversity course and the Advanced Bacterial Genetics courses as a graduate student. Although enrolled in an environmental microbiology program, she was focusing on aquatic chemistry during her graduate studies and her advisor was not a microbiologist. The Microbial Diversity course gave her an in-depth introduction to methods in environmental microbiology that would have been difficult to acquire so efficiently at her home institution. One of her fellow students in that very first course, who subsequently became a tenured professor in her native Venezuela, has become a life-long friend and is currently spending a sabbatical in Newman’s lab, which has facilities unavailable in Venezuela. Also at that first course, a visiting lecturer sparked an interest in bacterial genetics, which inspired Newman to attend the Bacterial Genetics Course at Cold Spring Harbor.

As a post-doctoral researcher, Newman was asked to serve as a teaching assistant for the Microbial Diversity course. She has gone on to lecture and serve as a faculty-in-residence. Students with whom Newman developed a mentoring relationship during the course have subsequently come to study or work as post-doctoral fellows in her laboratory. Newman considers this seamless transition from student to mentor to be one of the truly unique characteristics of summer courses.

Bill Metcalf was an E. coli geneticist when his mentor convinced him to attend the Microbial Diversity course. Metcalf credits that experience with giving him a broadened perspective on the microbial world that fundamentally changed the trajectory of his career. Like Newman, Metcalf also took the Advanced Bacterial Genetics course at Cold Spring Harbor making it possible for him to pursue research squarely at the intersection of microbial diversity and genetics as he applies traditional genetic methods to non-traditional microbes. Metcalf also has first hand experience of the role of summer courses in creating a multi-generational scientific community. His doctoral advisor was one of the founding faculty members of the Microbial Diversity course who then went on to direct the course for many years. Metcalf, in turn, served as a course director with Tom Schmidt. The course is currently directed by one of Schmidt’s former PhD students. It is a testament to the value of the courses that so many of their alumni are willing to invest their time and energy into maintaining them.
A colloquium participant noted that “the ‘summer camp’ atmosphere promotes the creation of a community”, a community that expands as each year’s participants become part of the courses’ alumni network. Colloquium participants discussed the fact that those courses aimed at creating new fields might have limited lifespans. One participant suggested that when the new fields become established enough that they became part of the regular university curriculum, the courses might no longer be necessary. Another participant described his experience directing a course once sponsored by NASA that served to recruit students into the field of astrobiology and was discontinued when a sufficient number of researchers had been trained (Box 2).

The second broad category of course aims to expose advanced students and established scientists to the cutting edge of established fields of study. These courses often have long traditions of presenting fundamental and long-established principles alongside the latest developments. This type of course is exemplified by the Microbial Diversity course at the Marine Microbiology Laboratory in Woods Hole, the Advanced Bacterial Genetics course at Cold Spring Harbor, the Host-Microbe Interactions Course in Spetses, Greece, and the Hopkins Microbiology Course at the Hopkins Marine Station of Stanford University. One colloquium participant described the goal of the Hopkins Microbiology course as “helping students develop an integrated view of the microbial world, and assembling what the world looks like from a microbe’s perspective. The course preserves a core knowledge of physiology which is at risk of being lost as we become more molecular.” These courses have both practical aspects (for example, learning the latest isolation and culturing techniques) and a conceptual dimension, as the students develop an integrated understanding of the current

Box 2: The Planetary Biology and Microbiology Course

In the 1980s, a summer course called PBME (Planetary Biology and Microbial Ecology) was designed and run by Drs. Lynn Margulis and Ken Nealson with the general goal of creating an interface between the emerging discipline of microbial ecology and NASA’s efforts in exobiology (the origin and evolution of life). When this course was started, there were few, if any venues available for such interdisciplinary education. The goals of the course were to expose a generation of students to this exciting new area, bring together faculty who might have common interests in exobiology and planetary science, but might otherwise not have met, and introduce promising young students to faculty with ongoing programs in exobiology and planetary science.

The course was funded entirely by NASA and included faculty from both the microbial ecology community and from NASA, in particular from the NASA Ames Research Center. NASA faculty covered a wide range of past and ongoing projects, while visiting microbiology faculty lectured on various aspects of biogeochemistry and microbial ecology. Laboratories were taught by world leaders in microbial ecology. Over the decade, the course focused on the cycles of carbon, sulfur, nitrogen, and metals, with the final course being focused on the use of modern (molecular) methods in the study of biogeochemical cycles.

PBME was transformative for NASA – it brought a large number of state-of-the-art microbiologists into close contact with planetary scientists at NASA – an impact that is still felt today at NASA. It truly served the catalytic function for which it was designed. In terms of summer courses, it might be reasonable to periodically consider whether there are emerging interfaces of microbiology with other fields that might benefit from a course that would catalyze new ideas and collaborations.
The course at Woods Hole strives to pass on to a new generation both the traditions and the current cutting edge of microbiology. Course directors there believe that it is important to have a cohort of researchers with a vivid appreciation of the significance of the microbial world, and how rapidly our understanding is changing, who appreciate the magnitude of microbial processes and the diversity of the microbial world, and who realize that the microbial world has implications for the entire planet.

**Intellectual freedom**

The courses issue no grades; no one is worried about his or her own research. A colloquium participant described the course atmosphere as an “intellectual playground” where new ideas and approaches can be pursued without penalty. Inherent to this intellectual freedom is the freedom to fail. Many students have had virtually all of their laboratory activities dictated by their teachers or mentors. Intensive summer courses may provide such students with their first taste of the real scientific process: developing good questions, designing appropriate experiments, and dealing with the inevitable unexpected results and failures.

**Opportunity to work in a unique environment**

Some of the courses take place in environments with unique characteristics. The Bermuda, Hawaii, Hopkins, and Geobiology courses all can draw on decades of time-series data characterizing their local environments.

**Opportunity to use cutting-edge technology**

All of the sites where these courses are held have access to technology that many students, especially those from resource-limited countries, would have no other opportunity to use.

**Opportunity to work on a diverse team**

During these courses, the traditional student-teacher hierarchy is loosened and even beginning graduate students become part of a group of researchers who treat each other as colleagues. Many courses recruit participants with a range of experience, from graduate students to senior faculty seeking training in a new field. All of the courses have several full-time and many visiting faculty; students get to see how senior researchers learn from and challenge each other. The students – sometimes for the first time – participate in and contribute to vigorous scientific debate.

All of the courses accept students from many different countries, and make an effort to include students of diverse ethnic, economic, and educational backgrounds. Participating in these courses can provide an important boost to students from resource-limited countries, small colleges, or other environments where contact with prominent leaders of the field is likely to be scarce. For students more fortunate in their backgrounds, the courses provide a chance to learn from colleagues who do
successful science with fewer resources. For everyone, the courses help to build the collegial networks upon which a thriving global scientific culture depends. The community bonds formed during these courses are enduring as evidenced by gathering of alumni at annual disciplinary research meetings, for example, Cold Spring Harbor alumni traditionally meet during the ASM General Meeting.

The course directors who are present for the entire course gain as much as the students from the intensive nature of the courses. All of the benefits described above are also enjoyed by these teachers. Many of the colloquium participants who have taught at the courses reported great satisfaction from seeing how the students develop and mature as the courses progress.

Faculty also benefit from the opportunity to meet and work with people they would not normally encounter. Faculty participants learn from outside speakers and from each other, and have more opportunity to interact than they would at a large general meeting. The courses are an ideal setting for the development of new research ideas and establishment of new collaborations, often across traditional disciplinary boundaries.

One colloquium participant said that he felt that the courses, at their best, provide a sort of “mini-sabbatical” for the faculty participants – a chance to leave one’s usual routine behind and explore new ideas with a diverse, intergenerational group of fellow scientists in a stimulating environment.
Advanced summer courses require a major investment

An essential ingredient in the success of these courses is the time commitment made by the faculty, especially those who organize and direct the courses. Despite the many benefits faculty derive from participating, past and present teachers emphasized that their participation in the courses was essentially a labor of love. They reported that time spent on the courses is uncompensated at best, and often in direct competition with the demands of their home institutions and research sponsors. Recruiting and coordinating the contributions of a critical mass of leading scientists requires a considerable investment of time from the organizers. Of all the resources needed to make these courses a success, this one—faculty time—is perhaps the crucial limiting factor to making such courses broadly available.

A second important ingredient for success is the small number of students. Courses are never larger than a few dozen students and participants say that keeping the numbers low helps the courses achieve a sense of community and of working on a single team. Expanding the number of students would substantially diminish the overall experience.

Finally, the courses often depend on scarce or expensive facilities, equipment, or services, or take place in environments where only a small group can be accommodated. Time and space on research ships, high-throughput sequencing runs, advanced computing capacity and access to fragile environments like the Yellowstone hot springs are just a few examples of the valuable and limited resources made available to participants in the courses.

The resource intensive nature of these courses means that there is little scope for economies of scale – a strategy to broaden the impact of the courses by ‘cloning’ them is not viable, given that securing funding for the current number of courses is already challenging. However, the colloquium participants had a number of ideas about how to leverage the resources invested in these courses and make at least some of their content and unique benefits more widely available.
The courses have many challenges in common

Common Challenge 1: Measuring impact

Systematic evaluation of impact has been a challenge for all of the courses. Course organizers have neither the time nor the expertise to undertake rigorous study of how much students learn or how the courses affect career choices and trajectories. Such information, however, is invaluable both for justifying continued investment in the courses by sponsors and faculty, and finding ways to make the courses better.

One working group at the colloquium explored how course evaluation could be improved. The first step, the group agreed, was to determine what the courses want to achieve; any evaluation process would then be designed to measure how well those goals were being met. Two kinds of goals were identified, those pertaining to Improvement in student knowledge and skills as result of participating on the course (goals 1-5) and the long term benefits to the discipline and the scientific community at large. (goals 6-8).

As a result of participating in the course

1) Students will be able to integrate different major concepts (e.g. physiology, genetics, evolution, population genetics, and ecology).

2) Students will be better equipped to make discoveries by learning how to identify good questions, hone hypotheses, and develop evidence-based processes for testing them.

3) Students will be better able to deal with and ultimately use experimental failures and unexpected results for refinement of processes and hypotheses.

4) Students will be better able to capitalize on emerging ideas and technologies.

5) Students will experience the conditions under which research actually takes place in a particular research field.

6) Students will be better equipped to learn from people with different expertise, approaches, and view points.
The greater scientific community will be served because the courses:

7) Develop the next generation of scientists for a particular field, and recruit faculty and students into new fields.

8) Build sustainable, cohesive scientific communities and networks thereby providing a tangible career benefit to participants at all career stage.

9) Attract the best and brightest graduate students and early career faculty to both traditional and emerging fields and build leadership capacity in microbiology and related fields.

Having identified a set of goals, the group talked about how best to measure whether the goals are being met. The process of evaluation is complicated because the goals are largely qualitative, and several of the desired impacts may take years to emerge. Many of the evaluation ideas described below are already in use by one or more of the courses.

- **Surveys**
  
  It was agreed that pre- and post-course surveys would be helpful, the goal being to determine what students already know on arrival, and what they think they’re going to learn and afterwards to ask what they did learn.

  Two survey instruments designed by the Howard Hughes Medical Institute (SURE (Survey of Undergraduate Research Experiences) and CURE (Classroom Undergraduate Research Experience) were suggested as potentially useful models for such course surveys. These tools provide suggestions on how to design questions, how to define a control group, and other factors that should be considered in developing a credible survey. The education experts in the group affirmed that many resources are available to help design evaluation instruments (listed in Appendix A); but the critical point is that a common platform for evaluation, if developed, could be used by all of the courses.

- **Advisory committees**
  
  Some of the courses recruit an advisory group to visit the course, interview students and solicit suggestions, sometimes give some lectures, and provide feedback to the organizers. The committees' advice is used to adjust course content and to demonstrate to sponsors that outside expertise has been sought and implemented.

- **Alumni tracking**
  
  One of the most powerful indicators of the courses' impact is the career path followed by their alumni. Do they: Pursue research careers? Undertake an interdisciplinary approach to their research? Use the latest technology? Pursue postdoctoral training with a course faculty member? Collaborate with fellow alumni? Each of these questions provides information as to whether the goals listed above have been met. It will be important to develop a mechanism to track participants over time to assess the impact the summer courses have on career trajectory. Social networks systems, like Linkedin and Facebook, should make this ever more feasible.
Requests for products

As described in the section on broadening the impact of the courses, colloquium participants suggested that while the overall course experience could not be provided to large numbers of students, in person or remotely, there was enthusiasm for the idea of designing the courses in such a way that some of the course content could be modularized and made available in the form of podcasts, discussion forums, problem sets and searchable or interactive datasets. Should this suggestion be adopted, tracking the use or purchase of such modules could be another tool for evaluation.

Common Challenge 2: Faculty recruitment and support

Each of the courses began because dedicated individuals were passionate enough about a particular field of science to devote countless hours to making a summer course happen. Organizing and running the courses is essentially a labor of love; the work is neither financially nor professionally rewarded. The lack of institutional recognition for the value of these courses was mentioned repeatedly.

Course organizers, who also serve as full-time faculty during the courses themselves, are responsible for obtaining funding, recruiting and selecting students, developing curriculum, recruiting faculty, and soliciting support in kind from equipment and reagent suppliers. It is also up to the organizers to gather student and faculty feedback to evaluate the impact of the courses. The dedication of these individuals to the courses is testament to their belief in the courses’ great value, but the amount of work involved is a deterrent to many and a significant impediment to expanding the number of courses.

Colloquium participants agreed that it is substantially easier to recruit faculty to participate in the courses for a few hours or days. But even for such limited involvement, there was concern that some of the most appropriate faculty—early career researchers doing highly innovative work—cannot afford to take the time off their work to participate. Concern about sacrificing precious hours of research time when school is out of session, difficulty arranging for child care, and concern that such activities would not be appreciated by tenure committees, were some of the reasons given for difficulty in involving this critical group of researchers.

Common Challenge 3: Outreach, student recruitment, and ensuring diversity

The courses are small, and need to remain so in order to retain their unique value. However, the fact that only a small number of students can benefit increases the pressure on course organizers to demonstrate that they are choosing from the widest possible pool and making a special effort to include under-represented minorities and students from a variety of backgrounds. Without substantial effort toward this end, courses are likely to be criticized as elitist or for perpetuating an ‘old-boys’ network. Thus to the director’s list of responsibilities must be added designing and implementing a plan for outreach, maintaining systematic records of applicants, and keeping track of who applies, where they come from, who gets in and who doesn’t.
Everyone agreed that one of the great values of these courses is that they can reach and benefit students who normally wouldn’t have such opportunities. Ensuring and demonstrating that this goal is being met is critical to maintain the courses’ credibility. Therefore it is important to keep track of whether students are mostly coming from labs of researchers who have taught in or participated in the courses, or whether students who come from the laboratories of faculty who’ve participated are more likely to be selected.

Common Challenge 4: Funding

The need to raise funds for each course each year is yet another major responsibility that falls largely on the course organizers. Course directors, faculty and former students, convinced of the value of the courses, are frustrated not to have a steady and predictable funding source. Meanwhile, sponsors need to be able to justify continued investment with convincing evidence of the courses’ continued high impact and relevance. While the dream of an endowment that would fund many of these courses in perpetuity was raised, the group recognized that the effort required to write a grant probably acts as an important ingredient in quality control: being forced to consider what has worked and what hasn’t, what new needs to be done, how the field is changing, etc., imposes a discipline on the organizer. Limited funding resources mean that the ‘market’ (of faculty willing to organize and teach, students interested in attending, and funders willing to continue sponsorship) will determine which courses are meeting a real need and which might have outlived their usefulness.
Increasing the impact of summer courses

The agencies and foundations that sponsor summer courses are naturally interested in learning about the return on their investment. When applying for continued funding, applicants are asked to describe the courses’ impact. As discussed above, a more comprehensive approach to course evaluation would provide invaluable data for renewal applications. But participants at the colloquium also brainstormed about how these courses could have impacts beyond their current audiences, so that both the sponsors’ and the faculty members’ investments could go even further.

The first suggestion was simple expansion, either by increasing the size of the current courses or by offering more of them. If they are so valuable, the argument goes, wouldn’t they have a greater impact if there were more of them, or if each included more students? Unfortunately, the considerable resources, both tangible and intangible, needed to launch and sustain the courses precludes simple cloning. And simply adding more students would imperil one of their most valuable qualities, that of creating an intimate small-group atmosphere. One exception to this general observation that providing more of these courses is prohibitively difficult is the establishment of similar courses in other countries modeled on successful courses in the U.S.

The group then discussed whether it would be possible to engineer a chain reaction: would it be possible to train course participants to bring what they learned at the summer courses back to their home institutions? This model is successfully employed in teaching courses, such as the Summer Institute at the University of Wisconsin, Madison (www.academiessummerinstitute.org). Faculty teams come to the Summer Institute to learn about science-based teaching methods and to develop curriculum modules they can put to use in their home classrooms. The Institute is now considering establishing regional institutes where similar courses would be taught by alumni of the national course. The group discussed whether such an approach could be adopted by the full-immersion summer courses. Would it be possible to create a system where participants could go off and offer similar courses elsewhere? This idea ran up against the same barrier as that of creating more courses in general. The problem is not a dearth of faculty capable of directing such courses, the problem is too few faculty in a position to volunteer their time to initiate and sustain the courses, and too few sponsor dollars to go around. The group therefore turned to imagining how it might be possible to extract more value from the courses as they are currently constituted—to make some aspects of the courses available to more students without diluting the value of the experience to the course attendees.
The principal idea that emerged was that of modularization. The group felt that it should be possible to examine the content of the courses and find ways to organize the curriculum so that some components could be provided to students off-site. The group suggested that it might be possible to re-structure the courses in such a way as to make it possible to provide two tiers. One tier would be for the students attending the course in person, essentially unchanged from the current courses. Another tier would be provided for students to attend on-line as “virtual” students. The on-line participants would not get the full hands-on experience, but it might be possible to include discussion sessions or other interactive and real-time features. Course alumni could be recruited to serve as tutors or mentors for the on-line participants. Tuition to attend the courses as a “virtual” student could be much reduced, making the courses accessible to a broader range of students and markedly expanding their impact.

It might even be possible to add a third tier, consisting of freely available course content. Such an approach certainly has the potential to make at least some of the course content very broadly accessible to students and faculty. With additional resources, such content could be organized to make it easy for teachers everywhere to incorporate the material into their courses. While attractive, this option also raised concerns; talks given at the courses frequently include unpublished data. Requiring that lecturers present only already published data would compromise some of the courses’ core goals—frank discussion of the latest science, as it is actually being done. Implementation of this third tier would require sorting out the issues of confidentiality, copyright, and maintaining publishing eligibility.

Technology is making such virtual education increasingly viable and there are a number of potential models to consider, including the OpenCourseWare project at MIT (http://ocw.mit.edu/index.htm). Indeed, the group even imagined a future on-line graduate university of microbiology, of which these courses could be the first offerings.

One component of many courses that seemed particularly amenable to creation of a ‘virtual’ module is that of data analysis. Public availability of data is, of course, one of scientists’ fundamental responsibilities, including both environmental (physical and biogeochemical) and molecular (-omics) observations from field and laboratory experiments without delay and in a user-friendly format. In the case of environmental microbiology, this includes metadata as well as detailed protocols for the methods employed and relevant information on quality assurance / quality control (QA/QC). Sharing of the interdisciplinary data collected during the microbiology training courses would serve as an excellent example of science collaboration for the future scientists in the discipline. Data sharing, ultimately, is a form of science communication and, as such, is an integral component of scientific training. Additional resources would be needed to develop an on-line data analysis module, but this was seen as a promising avenue for extending the reach of the current courses.
The Goldilocks Question: What mix of courses would be “just right”?

There is an enthusiastic constituency for each of the current summer courses. During the colloquium, many new ideas were generated for additional courses that would meet important needs in microbiology.

How many summer courses does microbiology need? What is the proper mix of courses? Do courses have a natural ‘life span’ after which they should not longer be offered? Who decides these questions? There was not felt to be a need for any kind of oversight or review of current courses; their independence and ability to adjust and improve their courses as they see fit is an important ingredient in their success.

The question of whether the current courses are continuing to meet a recognized need is answered by ‘market forces’, as represented by the grant-writing process. Courses survive only if they have committed volunteer directors and faculty who are able to convince sponsors to provide support. The group agreed that the requirement for ongoing justification for the courses is important, but also considered whether it would be useful to have a mechanism whereby the overall mix and content of courses could be evaluated. The goal would in no way be to institute central oversight over all of the courses, but instead to ensure that this extremely successful educational model is put to use as new opportunities and new needs emerge in microbiology. One possible approach would be to establish a committee of microbiologists from diverse areas of specialization that would meet on a regular basis to consider the mix of courses, solicit ideas for new courses and help identify and recruit faculty to take on the organization of new courses.
Recommendations

**CONTINUE TO SUPPORT SUCH COURSES**
Full-immersion courses currently meet an important need within the scientific community and merit continued support. The experience they offer cannot be reproduced in a typical university setting. If the courses were to disappear there would be a significant void in opportunities for the development of the next generation of cutting edge researcher and in the forging of interdisciplinary connections within the greater biological disciplines. The courses would be greatly missed if they disappeared.

**ESTABLISH A COMMON PLATFORM TO MEET COMMON NEEDS**
The many needs that the courses have in common, including evaluation, alumni tracking, outreach, fundraising, and faculty recruiting and support, could be made less onerous if a mechanism could be developed so that the courses could carry them out in a uniform way. For example, a central website offering pre-and post-course surveys, alumni directories, and links to individual course websites and application materials would be helpful. The American Society for Microbiology might be able to host such a site.

**CONVENE AN ADVISORY GROUP TO KEEP TRACK OF THE MIX OF COURSES OFFERED, IDENTIFY GAPS, AND FACILITATE THE ESTABLISHMENT OF NEW COURSES**
The mix of courses currently being offered has emerged piece-meal over the years and while the current courses have demonstrated their value by continuing to attract faculty volunteers, students and funding, there are likely additional topics for which this educational model could be highly successful and important to the progress of microbiology. Such an advisory group could facilitate the establishment of new courses when science and technology developments appear to create a need. The advisory group could also facilitate the establishment of similar courses world-wide. Such a group would have no role in the evaluation or administration of any current or future courses, which would always be the prerogative and responsibility of the course organizers; its role would be purely to provide a clearinghouse for information and a forum for exchanging ideas.

**FACILITATE AN ANNUAL MEETING OF COURSE ORGANIZERS**
A regular meeting would give course organizers the opportunity to share best practices, discuss issues of overlap and evaluate the utility of the central website. Such a meeting would be useful whether or not the advisory group recommended above is established, but there would be considerable opportunities for synergies between course organizers and an advisory group.

**TAKE ADVANTAGE OF ADVANCES IN TECHNOLOGY TO MAKE COURSE CONTENT AVAILABLE TO MORE STUDENTS**
The hands-on and personal aspects of the courses cannot be provided ‘virtually’, but many other components can be. An investment in the technology necessary to provide on-line access to lectures, data and analysis tools would allow the impact of these courses to be dramatically increased. Former students could be recruited to act as mentors and facilitators for on-line student participants.
Appendices

APPENDIX A: evaluation resources

HANDBOOKS & GUIDES

  This handbook provides a framework for thinking about evaluation as a relevant and useful program tool. It was written primarily for project directors who have direct responsibility for the ongoing evaluation of W. K. Kellogg Foundation-funded projects.

  This guide focuses on the development and use of the program logic model, which helps facilitate thinking, planning, and communications about program objectives and actual accomplishments.

  This handbook discusses quantitative and qualitative evaluation methods, suggesting ways in which they can be used as complements in an evaluation strategy.

  This Howard Hughes Medical Institute brochure describes the use of a logic model in formulating questions and defining the methods used to evaluate education programs.

ONLINE SURVEY TOOLS

- Student Assessment of their Learning Gains - [www.salgsite.org](http://www.salgsite.org)
  This website features a free course-evaluation tool that allows college-level instructors to gather learning-focused feedback from students.

- SURE and CURE surveys - [http://www.grinnell.edu/academic/psychology/faculty/dl/surecure](http://www.grinnell.edu/academic/psychology/faculty/dl/surecure)
  The Survey of Undergraduate Research Experiences (SURE) is a survey for undergraduates before and after a summer undergraduate research experience. The Classroom Undergraduate Research Experience (CURE) survey can be used to measure student experiences in research-based science courses.
APPENDIX B: websites for the courses

LABORATORY-BASED COURSES:

- Marine Biological Laboratory Microbial Diversity Summer Course (Woods Hole, MA) - http://www.mbl.edu/education/courses/summer/course_micro_div.html
- Marine Biological Laboratory Molecular Mycology Course - http://www.mbl.edu/education/courses/special_topics/momy.html
- Hopkins Microbiology Course - http://www.stanford.edu/class/cee274s/
- Bermuda Institute of Ocean Sciences (BIOS) Microbial Oceanography Summer Course - http://www.bios.edu/education/microb_ocean.html
- University of Southern California Geobiology Summer Course - http://dornsife.usc.edu/wrigley/education/geobio.cfm

LECTURE-BASED COURSES

- John Innes/Rudjer Bošković Summer Schools in Applied Molecular Microbiology - http://www.jic.ac.uk/science/molmicro/summerschool/