5

How Academic Institutions Can Facilitate Interdisciplinary Research

The previous chapter reviewed the environment and some of the challenges faced by individual researchers in approaching interdisciplinary research. This chapter reviews the opportunities and difficulties encountered by academic institutions that wish to facilitate IDR. Many institutions have become aware of institutional practices that create barriers to IDR; fewer have been able to lower or remove them. This chapter summarizes the barriers and describes how some institutions are trying to overcome them by reorganizing research, reallocating funds, and designing teaching programs conducive to interdisciplinarity.

A VISION FOR INSTITUTIONS THAT WISH TO PROMOTE INTERDISCIPLINARY RESEARCH

Ideas for IDR may be generated from the bottom up, by individual researchers who want to cross disciplinary boundaries alone or in collaboration with others, or from the top down, by institutions and funding organizations that initiate and support research and teaching. This chapter discusses both approaches from the point of view of the institution.

In the committee's survey, respondents were asked to rank the general supportiveness for IDR at their current institution and up to two previous institutions on a scale of 0 (IDR-hostile) to 10 (IDR-supportive). There appears to be a trend toward more supportive environments for IDR, but it is also possible that respondents purposefully moved to institutions that were more supportive (Figure 5-1). There appear to be interesting relationships between general institutional supportiveness for IDR and both budget

SURVEY

Institution's General Supportiveness for IDR from 0 (hostile) to 10 (supportive)

Environment for IDR	Convocation Survey (n=91)	Individual Survey (n=423)	Provost Survey (n=57)
Current institution	7.74 +/– 2.07	7.25 +/– 2.31	7.24 +/– 1.70
Previous institution(s)	5.95 +/– 2.17	6.35 +/– 2.57	5.67 +/– 2.04

FIGURE 5-1 Institutional environment for IDR.
NOTES: Respondents were asked to rank the general supportiveness for IDR at their current institution and up to two previous institutions on a scale of 0 (IDR-hostile) to 10 (IDR-supportive). Rankings are reported as mean +/– standard deviation. See Appendix E for more information on the three surveys.

and number of faculty. Respondents ranked their IDR experiences more favorably at institutions with budgets and faculty members at either end of the spectrum. This echoes findings by Epton et al.[1]

A vision of interdisciplinarity may begin with simple steps and behaviors that nourish the practice of collaboration. That might be done, for example, by creating more opportunities for faculty to work with students and postdoctoral fellows in different disciplines and departments. It might also be done by allocating seed money for space where a promising interdepartmental partnership can begin. One study notes that "interdisciplinary centers need not only to be well-funded but to have an independent physical location and intellectual direction apart from traditional university departments."[2]

Over half of the institutions represented in the committee's survey provided "venture capital" for interdisciplinary work. Amounts provided ranged from $1,000 to $1 million, but centered at $10,000-50,000 (Figure 5-2). Grant duration varied, but most tended to be 1- to 2-year awards.

A vision of interdisciplinarity might include a strategy to help young centers while they seek long-term support. For example, a university might give IDR high priority in its fund-raising and help to make the case with foundations to support an interdisciplinary strategy.

Or a vision might include a plan to broaden institutional participation wherein leaders can make the case for IDR through campus-wide meetings

[1]Epton, S. R., Payne, R. L., and Pearson, A. W. "Cross-Disciplinarity and Organizational Forms." *In:* Managing Interdisciplinary Research, Eds. Epton, S. R., Payne, R .L., and Pearson, A. W. Chichester: John Wiley & Sons, 1983.

[2]Rhoten, D. and Caruso, D. "Interdisciplinary Research: Trend or Transition?," *Items and Issues* 5(1-2):6, 2004.

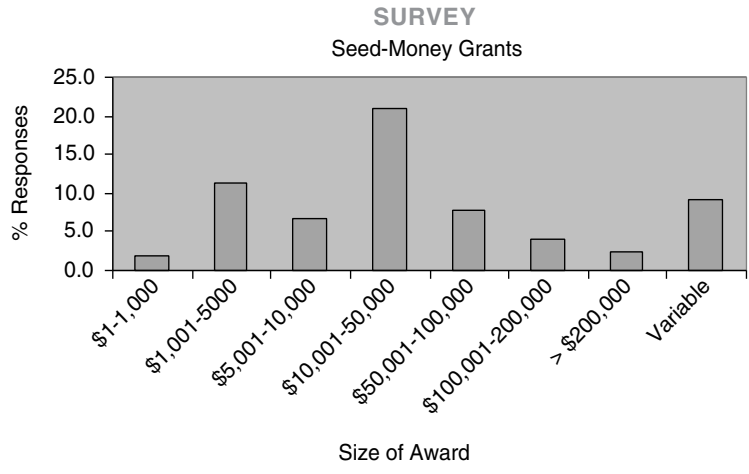

FIGURE 5-2 Size of seed-money grants.
NOTES: Respondents were asked whether their institution provided seed money to help start up interdisciplinary programs and were asked to briefly describe the amounts available and the major criteria used in making awards. Of the provost respondents, 87.7 percent indicated such awards were available. Interestingly, while 48.5 percent of the individual respondents answered yes, 27.2 percent were not aware of their institution's policy. Awards ranged from $1,000 to $1 million.

and discussions that air the needs of faculty and students.[3] Institutions can provide resources for curriculum development, student training in the use of equipment, and incentives for building synergies between IDR and teaching (see Box 4-2).

The top three recommendations for institutions from survey respondents were to foster a collaborative environment, to provide faculty incentives including hiring and tenure policies that reflect and reward involvement in IDR, and to provide seed money for IDR projects (Figure 5-3).

In practical terms, a vision might be implemented in many ways. To be effective, it would probably contain elements needed to overcome the barriers described in the next section.

[3]Roberts, J. A. and Barnhill, R. E. "Engineering Togetherness: An Incentive System for Interdisciplinary Research." ASEE/IEEE Frontiers in Education Conference. Reno, NV. October 10-13, 2001.

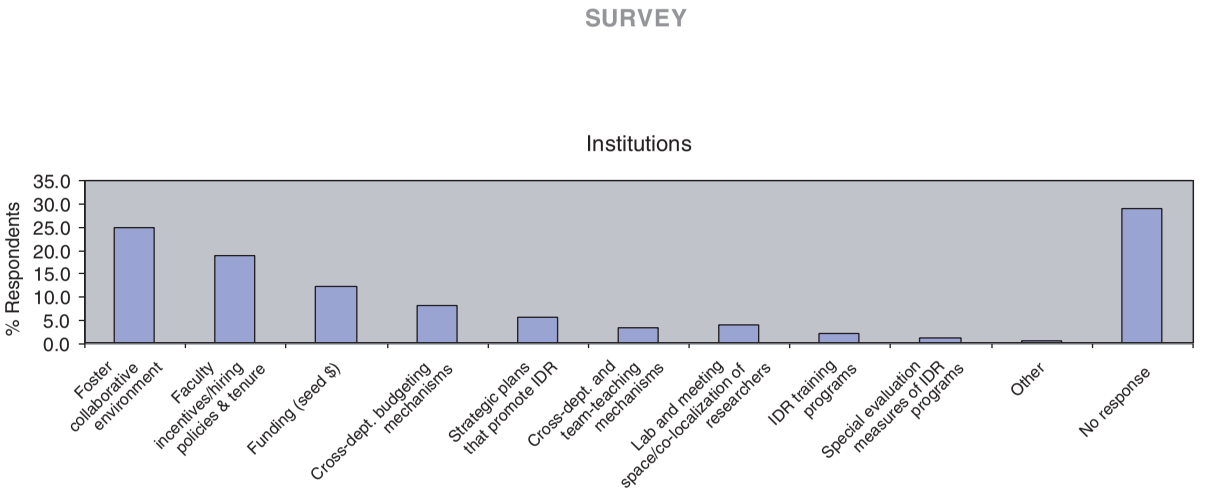

FIGURE 5-3 Recommendations for institutions.

NOTES: Survey Question: "If you could recommend one action that institutions could take that would best facilitate interdisciplinary research, what action would that be?" The top three recommendations for institutions (n = 341) were to foster a collaborative environment (26.5 percent), to provide faculty incentives (including hiring and tenure policies) that reflect and reward involvement in IDR (18.4 percent), and to provide seed money for IDR projects (11.1 percent). These recommendations and those for departments (Figure 5-5) reflect preconditions for IDR and are mirrored in recent self-studies carried out at the University of Washington (2002), University of Michigan (2000), and University of Michigan (1999), and by the American Association of Colleges of Pharmacy (2002).

SOURCE: Klein, J. T. and Porter, A. L. "Preconditions for Interdisciplinary Research." *In:* International Research Management Studies in Interdisciplinary Methods from Business, Government, and Academia, Eds. Birnbaum-More, P. H., Rossini, F. A., Baldwin, D. R. New York: Oxford University Press. 1990. pp. 11-19.

INSTITUTIONAL BARRIERS TO INTERDISCIPLINARY RESEARCH

Even the most supportive leadership must contend with substantial barriers that impede IDR. The committee's surveys suggested widespread awareness of barriers to IDR: 71 percent of respondents to the Individual Survey and 90 percent of respondents to the Provost Survey reported a belief that major impediments to IDR existed in their institutions. Barriers often stem from customs that have evolved over many decades, generally for sound reasons. It is ironic that some of the barriers are consequences of an otherwise excellent academic system that supports frontier research at every level and achieves great depth in training future generations of scientists. As shown by the boxed examples throughout this report, however, many institutions have developed practical ways to reduce the impediments.

Limited Resources

Of course, time and resources devoted to facilitating IDR are diverted from existing activities (both interdisciplinary and disciplinary). Starting a new program, providing new seed funds, or creating a new IDR center often means closing or reducing an effort in another area.

As a result, the institutional leadership needs to evaluate proposals for new activities carefully to ensure that they are not just satisfactory but outstanding. Some key mechanisms for doing so are to focus resources on activities with long-term implications and to involve high-quality senior faculty and promising junior faculty. Institutional leaders may also wish to establish an advising committee of faculty successful in IDR to evaluate proposed new activities; they are knowledgeable and likely to be sympathetic, and yet they are competitors for the same funds.

The Academic Reward System

Traditional academic systems for hiring, tenure, promotion, space allocation, and other rewards may constitute a substantial barrier to IDR (see Figure 4-5). At most academic institutions, hiring, tenure, and promotion are controlled by departments, and faculty often receive credit only for the teaching and research actually performed in their departments. Faculty who teach in interdisciplinary teams or classes outside the department may receive little or no departmental credit.

Different Institutional Cultures

Differences in culture—a set of customs, shared values, understandings, and relationships that pervade a discipline or unit—slow the communica-

tion and cooperation that underlie IDR.[4] The culture of a mathematics department, for example, differs in many ways from that of a biology department; potential collaborators may have to work hard to agree on such concepts as "proof" and "precision."

Convocation Quote

Most institutions have scientists in discrete departments, and while there are some enlightened institutions, there are many where if you are in biology, you are not allowed to speak to those nasty folks in chemistry, much less to sociologists, who are someplace else and you wouldn't know what to say to them even if you met them.

Lawrence Tabak, director of the National Institute of Dental and Craniofacial Research, National Institutes of Health

Program Evaluation

Traditional program evaluation evolved to review departments and associated education and training programs. A quick look at the listing of science, engineering, and humanities fields used by the National Science Foundation in its Survey of Earned Doctorates, for example, shows little change over the 40 years that the survey has been performed, 1960-2002. The same is true of the National Research Council in its Assessment of Research Doctorates. Academic institutions rely on such data to benchmark their programs and allocate internal resources (see Box 5-1). When emerging fields are not included in assessments, academic institutions tend to leave them out of the resource allocation as well.

Survey respondents were asked to describe evaluation methods used by their institutions to evaluate interdisciplinary programs. The predominant ones cited were internal and external visiting committees and informal feedback (see Figure 5-4).

Different Departmental Policies and Procedures

Departments and other units often balk at collaboration because of different administrative customs. Departments commonly differ over

- Allocation of indirect-cost recovery funds.

[4]Feller, I. "Whither interdisciplinarity (In an Era of Srategic Planning)?" Presented at AAAS Meeting, Seattle, WA, Feb. 15, 2004.

EVOLUTION

BOX 5-1 Assessing Research-Doctorate Programs[a]

Some researchers have questioned the reinforcing role of the National Research Council "rankings" on the "stiffness" of disciplinary boundaries and wondered whether and how new fields can or will be included in upcoming assessments. Certainly, university administrators pay great heed to the NRC assessments, and many base resource allocations—not to mention recruitment strategies—on them. Given the importance of the assessments, there is concern that emerging fields and extradepartmental programs, many of which are interdisciplinary, be included.

Partially in response to those concerns, the NRC recently completed a study to decide whether and how another assessment of research-doctorate programs should be conducted. The committee charge was as follows: "The methodology used to assess the quality and effectiveness of research doctoral programs will be examined and new approaches and new sources of information identified. The findings from this methodology study will be published in a report, which will include a recommendation concerning whether to conduct such an assessment using a revised methodology." The committee was informed through the deliberations of panels that considered taxonomy and interdisciplinarity, quantitative measures, student processes and outcomes, and measures of reputation and data presentation.

The committee concluded that undertaking the assessment again would be valuable and made specific recommendations with regard to taxonomy and inter-

- Organizing research and teaching.
- Allocating credit for multiauthor papers, especially when authors are in different disciplines or institutions.
- Control of space or capital-intensive facilities.
- Agreement on standards for recruiting and evaluating faculty with joint appointments.[5]

Among the top recommendations for departments listed by survey respondents were adopting new organizational approaches, recognition of faculty and researchers for interdisciplinary work, and adapting departmental resources and support for IDR (see Figure 5-5).

Lengthy Startup Times

Some kinds of research programs, and especially IDR, require long

[5]Feller, I., ibid., pp. 10-11.

disciplinarity concerning which fields and which programs within fields should be included in the study. While most of the criteria for inclusion of fields used in the earlier (1995) report were retained, it had new recommendations on the identification and listing of emerging and interdisciplinary fields. In particular, emerging fields should be identified based on the basis of their increased scholarly and training activity. The number of programs and degrees may not be sufficient to warrant full-scale evaluation at this time. If possible, emerging fields should be listed as subfields; otherwise they should be listed separately.

To gather data on programs and faculty, the committee recommended graduate programs be asked to identify those interdisciplinary centers within which their graduate students conduct research. Faculty would be asked to identify all the programs in which they taught graduate courses or supervised dissertations.

Finally, the report recommended some changes in broad fields and the inclusion of sub-fields to assist programs in placing themselves in the taxonomy:

- Fields should be organized into four major groups rather than the five of the previous Research Council study. Mathematics and physical sciences should be merged into one major group with engineering.
- Biological sciences, one of the four major groups, should be renamed "life sciences."
- Subfields should be listed for many of the fields.

[a]More information on the National Academies report "Assessing Research-Doctorate Programs: A Methodology Study (2003)" can be found at: *http://books.nap.edu/catalog/10859.html*.

startup times to arrange equipment, staffing, or infrastructure. Participants must delve deeply into another language and culture at the outset of a project.[6] Yet the policies and procedures specified by funding organizations and major universities do not always accommodate that need. The extra time required for IDR, even if well spent, can lead to fewer substantive results and publications, but the tenure and funding clock is not calibrated to take such activities into account.

Decentralized Budget Strategies

Most of the traditional academic budget is allocated to recurring categories, such as salaries, physical-plant costs, and instructional expenses. Flexible funds tend to be assigned to departments and colleges as operating

[6]Bruhn, J. G. "Interdisciplinary research: A philosophy, art form, artifact or antidote?" *Integrative Physiological and Behavioral Science*, Vol. 35, No. 1, January-March 2000, p. 62.

SURVEY

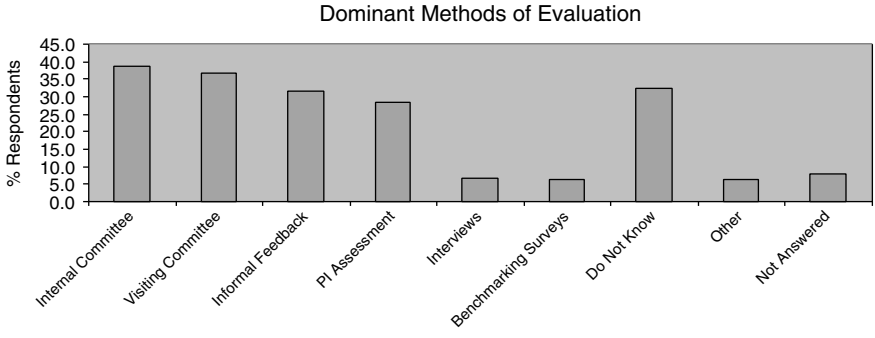

FIGURE 5-4 Institutional methods for program evaluation.
NOTES: Respondents were asked to describe dominant forms of evaluation used by their institutions to evaluate interdisciplinary programs. Institutions used multiple forms, the predominant methods being internal and external visiting committees, informal feedback, and PI assessment. Trends in evaluation methods reported by individuals and provosts were similar, but 37 percent of individual respondents were not aware of institutional evaluation policies.

SURVEY

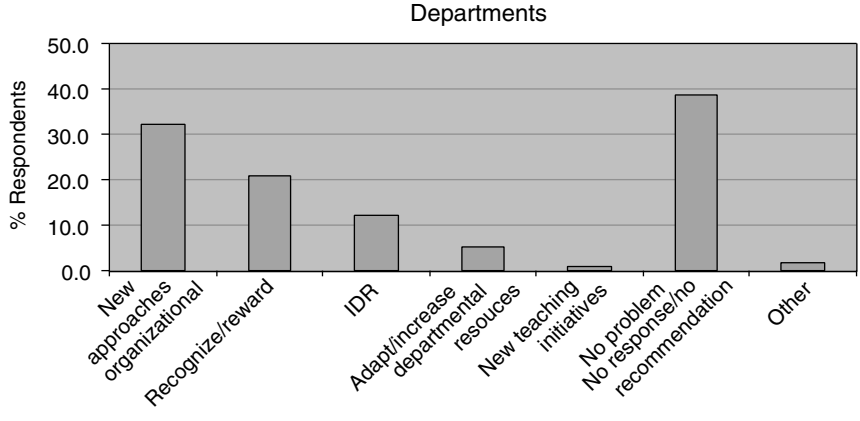

FIGURE 5-5 Recommendations for departments.
NOTES: Survey Question: "If you could recommend one action that departments could take that would best facilitate interdisciplinary research, what action would that be?" The top three recommendations for departments (n = 294) were to adopt new organizational approaches to IDR (32.1 percent), to recognize and reward faculty and other researchers for interdisciplinary work (20.8 percent), and to adapt or increase departmental resources to support IDR (12.3 percent).

units. As a result, central administrations often have scarce fiscal resources for initiating or sustaining IDR programs. Departments may be reluctant to contribute resources for activities not seen as directly beneficial.[7]

A NEED FOR SYSTEMATIC INSTITUTIONAL REFORM

The overall effect of barriers is hard to quantify, but even slight deterrents to researchers who are trying to reach career milestones—such as earning a degree, locating an academic position, raising funds, attaining tenure, publishing the results of research, or sustaining a long-term research portfolio—can become substantial and even onerous in the aggregate. This "accumulation of disadvantage," or theory of limited differences, has been discussed extensively in recent years, particularly as related to the disadvantages of women and members of other underrepresented populations in science and engineering.[8]

Many, perhaps most, universities are aware of the adverse effects of the barriers to IDR. Some have described reforms, placed them in strategic plans, and even allocated money for new initiatives. Few universities, however, have implemented systematic reforms to lower institutional barriers. A study that examined the interdisciplinary centers of major universities reported that "universities are failing to 'walk the walk'—or even to comprehend fully what doing so would entail."[9]

Still, some universities have begun to implement reforms, and it is on these new experiments and procedures that the present report focuses. As suggested in Chapter 4, the needs of students, postdoctoral fellows, and faculty change as they advance through the stages of a research career. The suggestions and examples in the next section are organized to reflect the progression of needs.

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[7]González, C. "The Role of the Graduate School in Interdisciplinary Programs: The University of California, Davis, Budget Model," Council of Graduate Schools *Communicator*, June 5, 2003.

[8]The concept of "accumulation of advantage and disadvantage" is discussed by Cole, J. R. and Singer, B. "A theory of limited differences: Explaining the productivity puzzle in science," in Zuckerman, H., Cole, J. R., and Bruer, J. T. eds., *The Outer Circle: Women in the Scientific Community*, New York: W.W. Norton, 1991, pp. 277-310; Merton, R. K., "The Matthew Effect in Science," *Science* 159, No. 3810, January 5, 1968, pp. 56-63; Zuckerman, H. A. *Scientific Elite: Studies of Nobel Laureates in the United States*, New York: The Free Press, 1977; and Sonnert, G. "Who Succeeds in Science? The Gender Dimension." Rutgers University Press, 1995.

[9]Rhoten, D. and Caruso, D. *Lead, follow, get out of the way: sidestepping the barriers to effective practice on interdisciplinarity.* The Hybrid Vigor Institute, April 2001, p. 4. Available at: *http://www.hybridvigor.net/interdis/pubs/hv_pub_interdis-2001.04.30.pdf.*

INNOVATIVE PRACTICE

BOX 5-2 Breaking Down Institutional Barriers by Breaking Bread Together

One of the overarching themes in facilitating interdisciplinary research is finding ways to bring together researchers who would not otherwise meet. In the committee's survey, the top recommendation was for institutions to foster a collaborative environment—to provide opportunities for interaction across disciplines and allow greater movement of faculty among programs and departments. That theme was echoed in recommendations to funding agencies, professional societies, and researchers themselves. One director called IDR "a body-contact sport—people have to be running into each other to make it work."[a]

To that end, several academic institutions have designed research centers with architectural features that promote collaboration, from cafeterias to shared laboratory space. As one director emphasized, "The last thing that I am going to shut down in my building is the cafeteria. It is tremendously important to bring people out of their buildings, out of their offices, out of their labs, and into a common space, and then they start talking."[b]

Even in industry, where laboratories are usually organized in interdisciplinary teams, common areas are important. "There is something about breaking bread together that causes creative juices to flow. If you go into our cafeteria at lunchtime, you find lots of interactions occurring. We have set up conference rooms around our cafeteria so that people can walk in there and start writing on easels or white boards or whatever. We promote collaborative work. We promote it because it is a way of life for us. It is what provides our bread and butter."[c]

At the other end of the cost spectrum is providing space for regular meetings of researchers across disciplines, departments, and colleges. "Despite the age of high technologies and computer communications, rubbing shoulders really still

FACILITATING INTERDISCIPLINARY RESEARCH AND EDUCATION

There is considerable overlap in activities between researchers at different stages of a research and teaching career, and the structure of this section is not intended to create artificial divisions. In fact, the concerns and goals of a student may be quite similar to those of a faculty member. For example, as indicated above, both students and faculty who wish to do IDR face difficulties in learning the language, culture, and knowledge of other disciplines.[10] Institutions can take the lead in providing incentives for stu-

[10]Metzger, N. and Zare, R. N. "Interdisciplinary research: From belief to reality," *Science* 283(5402):642-643, 1999.

helps."[d] Something as simple as providing institutional support for use of a meeting room can be pivotal in assembling a team. The Fred Hutchinson Cancer Research Center goes one step further and supports an "interdisciplinary club,"[e] which brings together graduate students, postdoctoral scholars, and staff researchers to discuss research ideas.

Funding organizations can help by providing venues or funding for meetings to discuss interdisciplinary topics. For example, the National Academies Keck Futures Initiative (NAKFI), sponsors annual conferences, to which about 100 scientists from different research settings are invited to participate in discussions centered on an emerging cross-disciplinary research theme.[f] As mentioned earlier in this report (see Box 2-4), dispersion, rather than multidisciplinarity, is often the most problematic aspect of interdisciplinary projects. Mechanisms that bring researchers together are effective in increasing project success.

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[a]Jeffrey Wadsworth, director, Oak Ridge National Lab. Comments made at Convocation on Facilitating Interdisciplinary Research, Washington, D.C., January 29, 2004.

[b]Pierre Wiltzius, director, Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign. Comments made at Convocation on Facilitating Interdisciplinary Research, Washington, D.C., January 29, 2004.

[c]Uma Chowdhry, vice president, Central Research and Development DuPont. Comments made at Convocation on Facilitating Interdisciplinary Research, Washington, D.C., January 29, 2004.

[d]Harvey Cohen, Professor of Pediatrics, Stanford School of Medicine and chair, Interdisciplinary Initiatives Program. Comments made at Convocation on Facilitating Interdisciplinary Research, Washington, D.C., January 29, 2004.

[e]Paulson, T. (2003) Grassroots Interdisciplinary Training: The FHCRC Interdisciplinary Club. Science's Next Wave, January 3, 2003 *http://nextwave.sciencemag.org/cgi/content/full/2002/12/30/7.*

[f]Keck Futures Initiatives Web site *http://www7.nationalacademies.org/keck/Keck_Futures_Conferences.html.*

dents and researchers to interact with other disciplines and to learn other languages and cultures (see Boxes 4-1 and 5-2).

Similarly, both students and faculty benefit from lowering the barriers to team teaching of interdisciplinary courses. For students, the exposure to teachers in different disciplines can lead to understanding that is broader than a single discipline. For faculty, the ability to collaborate with teachers in different disciplines may lead to new understandings of their own and an ability to describe their work to students in different majors. Institutions facilitate both research and teaching when they support team teaching through better methods to recognize and reward teachers who are teaching outside their departments, through teaching-credit policies that sustain team-taught courses, through opportunities for students to acquire mentors in multiple disciplines and with different perspectives, and through stronger support for departments engaged in team teaching (see Box 4-2).

Convocation Quote

We have had to put a lot of care into how we are a community and what we do to keep that growing. I think that as we aged a little bit and we had more people involved—more students and more faculty mentors—we suddenly hit "critical mass." There was a big difference; there was momentum.

Marye Ann Carroll, professor,
Atmospheric, Oceanic, and Space Sciences, Univ. Michigan

The intent of this section is not to differentiate, but to point to common themes. To oversimplify somewhat, institutions can best facilitate IDR by considering the drivers of IDR discussed in Chapter 2: creating collaborations capable of addressing the enormous complexity of nature, allowing students and faculty the flexibility to explore the interfaces between disciplines, extending partnerships to the humanities and other sectors required to address complicated societal problems, and providing access to and understanding of the "generative technologies" whose full exploitation may lead to new fields and new ways of looking at existing fields.

Undergraduate Education

Undergraduate students often show great enthusiasm for interdisciplinary and problem-driven questions, including those of societal relevance. There are many ways in which institutions can design undergraduate (or even high school) programs that take advantage of that natural interest:

- Undergraduate interdisciplinary degree programs: The number of interdisciplinary undergraduate majors has begun to grow in recent years, and numerous models are now available.
- Undergraduate research programs: The variety of research experiences for undergraduates (REUs) is increasing rapidly, and students have responded with strong interest.[11]
- Topics of high societal relevance: Offering courses or programs on such topics may attract a different mix of students, including those who want to perform research of practical use.
- Programs that offer depth in more than one discipline: Multiple skills can be developed by a broader training program, including studies and internships in other fields, exercises in combining approaches of mul-

[11]At the University of Michigan, students participating in REUs have higher rates of retention in science and engineering. 1996 Assessment of the Undergraduate Research Opportunity Program. Available at *http://www.undergraduate.research.umich.edu/homeassessUROP.html.*

INNOVATIVE PRACTICE

BOX 5-3 IDR at Primarily Undergraduate Institutions[a]

Undergraduate research is a growing phenomenon. The Council on Undergraduate Research (CUR),[b] founded in 1978, supports and promotes high-quality undergraduate student-faculty collaborative research and scholarship. CUR has 3,000 members representing over 870 institutions in eight academic divisions. Much of this research is interdisciplinary. For example, Haverford College, an undergraduate institution with about 1,100 students, is on the cusp of a major change in curriculum. Its plan for the next 5-10 years is to do away with general courses in chemistry, physics, and biology and to teach them integratively. The idea is to teach chemistry and physics as an integrative course in the first year, providing foundations for further work in the disciplines and a foundation for an integrated course in organic chemistry and molecular biology. The first 2 years of the curriculum would emphasize mathematics and statistics.

In the junior and senior years, there is already a fairly broad curriculum that is taught in an interdisciplinary way. Juniors in the chemistry, biology, and physics departments take introduction-to-research-methods courses instead of traditional laboratory courses. These intensive courses last for the entire school year.

In the senior year, students are immersed in research. That is, research is integrated into the curriculum: students are introduced to research methods instead of having to learn physical and chemical laboratory methods, inorganic and organic chemistry, and so on. All these concepts are pulled together into a single laboratory course, which is going to be expanded by units on material science, computational biology, neuroscience, and biophysics, in which students will navigate from module to module across the involved departments. The plan is to weave research and interdisciplinary work completely into the fabric of the curriculum of all the science departments.

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[a]Julio de Paula, Professor of Chemistry, Haverford College, comments at the Convocation for Facilitating Interdisciplinary Research, Washington, DC, January 30, 2004. *http://www7.nationalacademies.org/interdisciplinary/Convocation_Agenda.html.*

[b]*www.cur.org.*

tiple disciplines, communication, and opportunities for portable scholarships, summer laboratory jobs, and industrial internships.

Graduate Education

While graduate students are building a firm base in their primary discipline, they may become familiar with additional fields or skills that can extend their knowledge. To facilitate the ability of graduate students to ground themselves in interdisciplinary thinking, institutions can provide

- Programs with many of the same general features as undergraduate interdisciplinary courses but with added complexity and depth.
- Additional exciting research at the interfaces of disciplines, including opportunities to work with and learn from graduate students in other disciplines and multiple advisers who bring diverse perspectives to research problems.
- Additional academic recognition and funding that allow graduate students in IDR to anticipate prospects for advancement equal to those of single-discipline students.
- Graduate IDR internships, including assistance in finding appropriate academic "homes"; these are needed when departments are unable or unwilling to accommodate researchers doing interdisciplinary work.
- Experience in using instrumentation and other techniques that are beyond the inventory of a single adviser or discipline.
- Dual mentors who may bring different perspectives to the same problem.

Postdoctoral Fellowships

For postdoctoral scholars, there is no substitute for honing expertise in one discipline; even researchers who direct interdisciplinary teams prefer members who are expert in at least one field rather than "masters of none." At the same time, many postdoctoral scholars are ready to benefit from complementary expertise in another field. Institutions can enrich the postdoctoral experience by providing

- Opportunities to interact with specialists in other disciplines and to learn the language, culture, and knowledge of a new discipline.
- Scholarships for gaining a master's degree in another field.
- Attentive mentoring by multiple mentors, with annual reviews so that postdoctoral scholars do not "fall through the cracks."
- Access to a broader array of instrumentation and analytical techniques.
- Appropriate referees and mentors who will support the inclusion of IDR in tenure decisions.
- Opportunities to undertake study in a foreign country.

Hiring

Interdisciplinary faculty hiring requires changes that start long before the candidate is hired during the search and interview processes. Most search committees reside within a department or discipline. If interdisciplinary search committees are formed, successful searches require that the

relationship between these and the departmental search committees be agreed on and well understood. Interview schedules, also often the responsibility of department committees, must cut across departments. Department administrators must negotiate terms of joint appointments, including startup resources and space. Institutions have experimented with ways to lower the barriers to hiring junior scientists working in IDR that were described in Chapter 4. Some have adopted institutionwide hiring policies that promote IDR (see Box 9-5). Others have provided transitional funding for hiring interdisciplinary people. The University of Wisconsin uses a "cluster hiring" program (see Box 5-4), and Arizona State University has split departmental appointments for more than a decade.

Here are other examples:

- Columbia University has allocated 15 faculty lines, mostly to junior faculty, agreeing to pay salaries for the first 5 years with departments to assume support thereafter. This incentive program is funded by intellectual-property revenues.
- The National Center for Atmospheric Research reserves four slots per year to hire assistant professors with interdisciplinary interests. The institution and the departments each provide half the support.
- The California Institute of Technology has plans to hire about 25 interdisciplinary faculty in information technology.

Research institutions also have increasing needs to hire and provide a career track for scientific managers, as recommended in the National Research Council report on team science.[12] The managers, in turn, would need thorough interdisciplinary training.

Junior Faculty

Junior faculty can benefit from many of the same research opportunities as postdoctoral scholars. In addition, modest institutional changes can help them to overcome departmental or professional barriers:

- Institutional funding for junior faculty positions can include more flexible teaching placement.
- The work done by faculty in interdisciplinary centers or team-teaching situations should count with equal credit toward promotion and tenure.

[12]National Research Council. 2003. Large-Scale Biomedical Science: Exploring Strategies for Future Research. Eds. Nass, S. J. and Stillman, B. W. Washington, D.C.: The National Academies Press.

INNOVATIVE PRACTICE

BOX 5-4 The Cluster Hiring Initiative at the University of Wisconsin

The Cluster Hiring Initiative (CHI)[a] at the University of Wisconsin at Madison (UW) grew out of the campus strategic planning process of the middle 1990s. The initiative involved a provost-coordinated campuswide competition to identify groups of new faculty hires, or "clusters," to work together on interdisciplinary programs and emerging fields of inquiry.

By establishing the CHI, the campus acknowledged that existing curriculum demands, department traditions, and faculty governance may limit department opportunities to pursue new directions in faculty hiring. Departments may be unable to hire faculty who pursue important new, more experimental, less established lines of research or interdisciplinary research that is by definition distant from the core of a single discipline. The prevailing academic cultures and structures tend to replicate existing areas of expertise, reward individual effort rather than collaborative work, limit hiring input to a single department in a single school or college, and limit incentives and rewards for interdisciplinary and collaborative work.

The provost invited proposals from faculty that identify promising subjects for faculty collaboration. Since 1998, faculty have submitted hundreds of proposals to fund faculty lines to pursue and develop new and promising areas of interdisciplinary and collaborative inquiry. These are permanent lines that remain with the hiring department as long as a cluster faculty remains with the university. The campus has conducted five phases of cluster identification and funding. Through 2003, 49 clusters with 137 new faculty lines were authorized with central funding, and schools and colleges matched six additional cluster faculty positions.

The provost-appointed Faculty Advisory Review Committee is composed of one person from each of the four divisional and research committees and two at-large members appointed by the chancellor. Coordinated by the assistant vice chancellor for faculty and staff programs, the committee evaluated preproposals and full proposals against five criteria[b]: quality and merits of the initiative, relevance to the mission and vision of UW, timing, potential for success, and potential for faculty diversity.

Some departments have used cluster positions to add to or strengthen their department core disciplines. In other cases, clusters strengthened existing interdisciplinary programs. An evaluation committee[c] heard more enthusiasm than criticism about the promises and activities of the initiative. However, faculty expressed concerns about tenure review, salary equity, and infrastructure support:

- Faculty should receive equal credit at their home institutions for contributions to interdisciplinary or multidisciplinary journals or conferences.
- Faculty can be permitted to request reviews in other fields at the third year and to request review panels that include extradepartmental expertise (see Box 5-5).

Tenure Review: Departments and divisional committees found it difficult to evaluate a cluster faculty's interdisciplinary scholarship during the tenure review. However, an ad hoc interdisciplinary committee report[d] showed "no difference in the likelihood of achieving tenure among probationary faculty with multiple appointments compared to those with appointments in only one department." In fact, data from this ad hoc report showed that "the likelihood of achieving tenure is not lower but in fact higher for candidates with joint appointments or multiple tenure homes." A similar concern about documenting scholarship for tenure was expressed recently by the campus clinical faculty; however, a committee that examined this concern found no evidence that clinical faculty were achieving tenure at a lower rate than other faculty in the health sciences.[e]

Salary Equity: The committee did find that CHI appointments across school and college lines have increased faculty awareness that courses taught, salaries, and startup packages differ widely with the field and area of specialization. As cross-college and cross-department appointments increase, the campus may need to pay more attention to merit processes that involve input from schools, colleges, and departments with which cluster faculty are involved.

Infrastructure Support: In response to the identified need to foster cluster infrastructure, the provost established a campuswide Cluster Hiring Enhancement Grant competition to provide partial support for graduate students, program assistants, and laboratory assistants and other expenses related to programmatic activities.

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[a]Cluster Hiring Initiative Program Description, Office of the Provost, University of Wisconsin. Homepage *http://wiscinfo.doit.wisc.edu/cluster/progrmdesc.html.* Accessed April 30, 2004.

[b]Cluster Hiring Initiative Program Overview and Guidelines, Office of the Provost, University of Wisconsin. *http://wiscinfo.doit.wisc.edu/cluster/overviewr5html.* Accessed April 30, 2004.

[c]*Report of the Provost's Ad Hoc Advisory Committee to Evaluate the Cluster Hiring Initiative University of Wisconsin-Madison.* Submitted to the Provost, November 11, 2003. (Coordinator, Linda Greene, Associate Vice Chancellor for Faculty and Staff Programs).

[d]The provost's Ad Hoc Committee on Faculty in Interdisciplinary Programs, chaired by Elizabeth Thomson, appointed by the provost to identify potential disparities in responsibilities and rewards between faculty with interdisciplinary responsibilities and those without, submitted its report to the provost on March 8, 2003.

[e]*Report of the Health Sciences Division Task Force on the Health Sciences Division Proposal* submitted to the Deans of the Health Sciences Schools, April 23, 2003 (Chair Professor John Mullahy, Dept. of Population Health Sciences) Appendix F, pages 75-76 and Appendix I pages 89-90.

Tenured Faculty

Tenured faculty are often more active in IDR than junior faculty because their career positions are secure. But institutions can help senior faculty through several modest policy changes:

- Developing incentives that allow faculty to continue their education in fields complementary to their own.
- Creating mechanisms for interdisciplinary work or projects to be evaluated by panels on which multiple disciplines are represented.
- Providing more opportunities for faculty to learn from students and postdoctoral scholars in other fields.
- Using seed money to fund sabbaticals and visiting-scholar grants for faculty to work in multidisciplinary groups.

Convocation Quote

Rockefeller University really understands what research is about. Research is focused on a problem. You find the tools, solve the problem. So, a year after I was hired, they asked me, "By the way, what is your title?" That is the appropriate response to a professor. Let the professor tell you what he or she wants to do.

Joel Cohen, Abby Rockefeller Mauze Professor, Laboratory of Populations affiliated with both Rockefeller University and Columbia University

All Faculty

Some of the most important reforms that institutions can undertake apply to both junior and senior faculty. They include these:

- Reward structure: Faculty who conduct IDR need professional recognition comparable with that given to faculty who conduct single-discipline research.
- Faculty evaluations: Academic leaders can make special efforts to overcome departmental or disciplinary bias in reviewing (see Box 5-5). Faculty are treated fairly when they are evaluated on the basis of all their work—not just the work in the discipline of their home departments.
- Publication credit: Faculty benefit by receiving institutional credit for work reported in journals or conferences outside their specialties or in interdisciplinary journals.
- Allowance for long startup times: Universities can be flexible with respect to time in their tenure-review processes or allow longer probationary time for nontenured faculty when some or all of their contribution is interdisciplinary.
- Curricular integration: A curriculum that allows formal placement of IDR on the teaching agenda provides a strong, visible endorsement.

TOOLKIT

BOX 5-5 Providing for Interdisciplinarity in the Tenure and Review Process[a]

At the University of Southern California (USC), IDR gained prominence in 1994, owing to a new strategic plan that called for the development of undergraduate research programs focused on IDR.[b] "Ideas can bubble up from the bottom, but they need to be embraced by the top," explained Neil Sullivan, USC vice provost for research. Sullivan's primary responsibility is to facilitate multidisciplinary research across the university.

Several mechanisms have been put into place to encourage IDR:

- *Research and Incentive Fund:* For inhouse peer-reviewed proposals for projects from more than two faculty members in more than two schools of the university.
- *Faculty Fellowships:* Up to $50,000 for IDR proposals and release from teaching. Proposals are reviewed by other faculty members at the university. Awardees meet monthly to make presentations and give progress reports, and their advice is solicited by the vice provost on ways to break down barriers to IDR.
- *Specific Guidelines:* USC has added explicit language in its promotions and review criteria for interdisciplinary scholarship and teaching, and IDR was specifically addressed in the provost's cover letter with the guidelines.[c] Within the guidelines, specific points address IDR:

> If a candidate's scholarship is interdisciplinary, the department and school should take special care to evaluate the work properly. If work does not match the departments' priorities, but does further the school or University policies, that should be explained. The evaluation of quality and quantity should be distinguished from discussion of how the work fits strategies for excellence.

Regarding selection of referees, the guidelines state:

> For interdisciplinary scholarship, the lists of external referees should include experts from the other discipline, as well as experts in the individual's own type of interdisciplinary scholarship.

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[a]From an interview with Cornelius Sullivan, Vice Provost for Research, USC, November 10, 2003.

[b]University of Southern California 1994 Strategic Plan: *http://www.usc.edu/about/strategic_priorities/strategic_plan94.html*.

[c]"Guidelines of the University Committee on Appointments, Promotions, and Tenure." University of Southern California, issued October 27, 2003. Available on-line at *http://www.usc.edu/policies*.

Institutional Leadership

Promoting IDR often begins with the central administration. Presidents, provosts, vice presidents for research, and other leaders have high visibility and good access to resources. According to the literature, the more open a person is to new experiences, the more creative he or she is likely to

TOOLKIT

BOX 5-6 The Beckman Institute at the University of Illinois, Urbana-Champaign[a]

The origin of the Beckman Institute at the University of Illinois is a story of interdisciplinarity. In 1983, the vice-chancellor for research appointed two faculty committees–one in the physical sciences and engineering, the other in the life and behavioral sciences—to explore the prospects for a radically new, campus-based research institute that drew on university disciplinary expertise and interests.

UIUC presented Dr. and Mrs. Arnold Beckman with the committees' proposal to create in a state-of-the-art institute an integrated array of research efforts that would be a model of interdisciplinary research. In 1985, the Beckmans awarded the University of Illinois $40 million for construction of the institute, and the state of Illinois made added commitments. The institute, a 300,000-ft^2 facility, began operations in early 1989. Many special features novel for academic settings and intended to foster interactions were incorporated into its design.

Faculty Affiliations and Reporting Structures: The director of the institute has the status of a dean and reports to the provost. All faculty in the institute have appointments in departments and maintain departmental teaching and service obligations. Some faculty are full-time; that is, all their research activities are centered in the institute. Others are part-time; they maintain some research space in the institute and some in departments. Still others have looser affiliate appointments; they are involved in an institute program and may have students or postdoctoral fellows working there, but they do not maintain offices. About 130 faculty are affiliated with the institute, with some 400-450 graduate students, 200-300 undergraduate students, and 70-80 postdoctoral fellows. A staff of 60-70 provide technical and administrative support.

Research Programs and Evaluation: The institute is organized along themes that cross-cut and build on university strengths in the physical sciences, engineering, and the cognitive and social sciences. Each of the major research themes is

be. That implies that openness should be taken into consideration when selecting a person to head an interdisciplinary education or research program if it is to be effective.[13] It is up to institutions to recognize innovative,

[13]Feist, G. J. and Gorman, M. E. 1998. The Psychology of Science: Review and Integration of a Nascent Discipline. *Review of General Psychology* 2, no. 1:3-47; Simonton, D. K. 2004. *Creativity in Science: Chance, Logic, Genius, and Zeitgeist*. New York: Cambridge University Press; Simonton, D. K. 2003. Scientific Creativity as Constrained Stochastic Behavior: The Integration of Product, Person, and Process Perspectives. *Psychological Bulletin* 129, no. 4:475-94.

evaluated every few years with the help of external experts. Is the work being done of the highest caliber? Is the research of individual faculty or groups of faculty taking advantage of the uniqueness of the institute? Is it interdisciplinary? When a review is unfavorable, the director has the duty to require faculty or groups of faculty to leave the institute and return to their home departments. The review process is important in the success of the institute. Turnover of research programs and individuals is essential to the institute's long-term vitality.

Relations with Departments and Colleges: Because the institute stands apart from the traditional college and departmental organization of the university, its relations with departments and colleges require continuing attention. Campus policy provides for sharing of indirect cost returns (ICRs) on grants with colleges and departments. For grants that involve a single investigator, or a group of investigators from a single department, the ICRs will all accrue to the home department, even though the work was performed in the institute. However, the ICRs on multi-investigator grants involving faculty from different departments pass to the institute. That rule has occasioned some controversy, especially regarding large grants involving many faculty.

The institute participates actively in the recruitment of new faculty when a department's interests intersect productively with those of Institute programs. Funds for equipment, student support, and other research needs are regularly allocated from those available in the institute and departments and colleges negotiate over how faculty allocate their time and interests to departmental and collegial affairs as opposed to institute affairs.

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[a]Pierre Wiltzius, Director, Beckman Institute for Advanced Science and Technology, and Professor, Materials Science and Engineering Department and Physics Department, University of Illinois at Urbana-Champaign. Based on comments at the Convocation on Facilitating Interdisciplinary Research, Washington, DC. January 29, 2004. Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign, Web site *http://www.beckman.uiuc.edu/*.

flexible leaders and to encourage them to take risks in discerning and supporting fresh ideas.

Incentives and Rewards

One cause of turf battles between departments is that deans, department chairs, and other administrators are rewarded for strengthening their own departments, not for building links to others. Institutions can reward leaders for initiating interdisciplinary programs and can provide incentives for departments to share indirect cost revenues, seed money, course-credit

assignments, intellectual property, space, personnel, and other resources[14] (see Box 5-6).

Promoting Interactions

Institutions can also facilitate the natural development of departments as their researchers continually seek interaction with other disciplines.[15] Good leadership can assist interdepartmental interactions, which are often hindered by organizational structures (see Box 5-7). In particular, increased interaction with those outside one's department should be rewarded through the promotion and tenure process.

Biology, for example, has developed extensive interactions with mathematical science; this reflects the discipline's need for powerful quantitative tools. Despite that development, the two disciplines remain largely distinct at the institutional level. Often, the same barriers that hold back IDR hold back the natural evolution of the disciplines themselves.

Convocation Quote

Keeping a team motivated through ups and downs and through years of striving because nobody has done this type of work before takes a lot of . . . emotional intelligence. It takes understanding human behavior. It takes understanding human interactions and what keeps people motivated.

Uma Chowdhry, vice president for
Central Research and Development, DuPont

Budget Reforms

Most major universities have developed decentralized budgeting models in which the lion's share of resources flows to schools, departments, and other units. This leaves relatively few resources to be used for "the com-

[14]An example of such a policy could be seen until recently at the Massachusetts Institute of Technology, where the administration allowed the use of the old Building 20 as a home for new, often interdisciplinary.

[15]As Blau has written, "The distinctive departmental structure of American universities makes it relatively easy to offer positions to specialists in new fields who work at the frontiers of knowledge, at first within departments and later, as the specialty grows, by establishing a separate department for it." Blau, P. M. *The Organization of Academic Work*, New York: John Wiley & Sons, 1973, p. 194.

TOOLKIT

BOX 5-7 Stirring the Pot

Several institutions help researchers with similar interests cross departmental boundaries to respond to funding initiatives. Some have full-time staff associates (see Box 4-5); others rely on the vice provost for research. At the State University of New York (SUNY) at Stony Brook, Associate Vice President for Research Martin Schoonen brings teams together to respond to requests for applications (RFAs) and broad agency announcements.[a]

Schoonen's position is split 50:50 between a 3-year associate appointment as vice president for research and his position as professor in geosciences. The Office of the Vice President for Research maintains a Web page of annual program solicitations and distributes announcements for interesting talks on campus, high-profile papers, and the like. Says Shoonen: "I purposely do not organize seminars. I found that faculty are not looking for more talks to go to. They will come to a meeting if there is a funding opportunity."[b]

As a result of his matchmaking, at least two major projects have received funding. One was a US Agency for International Development award to help to rebuild Iraqi institutions of higher education.[c] The second was a National Institutes of Health award that brings together faculty interested in drug discovery and in tropical ecosystem conservation.[d]

For a pending NIH training grant with three other institutions and about 100 possible mentors, his office organized meetings to get potential mentors to sign on. They brought together a diverse group of faculty representing medical science, social science, environmental science, physical science, and economics. Virtually all paperwork associated with the grant application was handled by the Office of the Vice President for Research.

Efforts that have not led to awards have nevertheless been good investments in community-building. Some subsets of proposal-team members are working together on a small scale—for example, an economist with a nutritionist, a materials scientist with a microbiologist, and an environmental scientist with a virologist.

When an RFA calls for a multidisciplinary or interdisciplinary approach, he often "starts with calling some people I know. If there is some interest, I will convene a meeting. The meeting is announced campuswide. I have developed this strategy so that I know there will be some interested faculty (contacted directly by me) at the very least." However, through the campus announcement, he usually uncovers some additional people. For example, "our dean of libraries became a key player in the Iraq proposal. It turned out he had been trained in Near Eastern culture, can read Arabic, and had set up a library in Egypt." Once the team is formed, he guides them through the maze of proposal paperwork, reminds them of deadlines, helps organize meetings to work on the proposal, and creates an electronic home so that faculty can share files.

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[a]Martin Schoonen, Associate Vice President for Research and Professor of Geochemistry, State University of New York, Stony Brook. Comments at the Convocation on Facilitating Interdisciplinary Research, Washington, DC. January 29, 2004.

[b]Martin Schoonen. Personal Communication. April 21, 2004.

[c]See *http://commcgi.cc.stonybrook.edu/artman/publish/article_573.shtml.*

[d]See *http://icte.bio.sunysb.edu/pages/ICBG_project.htm.*

TOOLKIT

BOX 5-8 Making Money Flow Sideways: Budgeting Models at UC Davis and the University of Michigan

University of California, Davis[a]

The proliferation of interdisciplinary programs in the 1970s challenged the old "vertical" funding model at universities with more "horizontal" programs that cut across college lines. "Money naturally runs downhill," writes Cristina Gonzalez, "and it is hard to make it flow sideways." UC Davis experimented with two ways to overcome this "law of gravity": distribute funds from a central office directly to interdisciplinary programs without going through the deans, and bring matching funds from a central office, such as the graduate school, to support the program.

UC Davis still does both, with increasing emphasis on matching funds. The Office of Graduate Studies (OGS) has the key role in supporting interdisciplinary programs, with an enrollment-based funding formula for administrative support of graduate groups. A few years ago, the formula was updated with a system of matching funds between the OGS and the college deans with the understanding that future matches by the college deans would come from their own budgets.

Gonzalez concluded that although the system works at UC Davis, universities have become too complex for a one-size-fits-all solution to the funding challenges of interdisciplinary programs. "Making money flow horizontally in a vertical funding system," she writes, "is highly customized engineering work that must take the individual characteristics of each campus into account."

University of Michigan[b]

The University of Michigan recently (FY 1998-1999) changed its budget model in ways more favorable to the management of interdisciplinary work, especially extradepartmental programs categorized as organized research units. In contrast with the previous system of "value-centered management," or incremental budgeting, the new budget system provides a mix of activity-based and discretionary budgeting. In activity-based budgeting, revenues flow preferentially toward units that are credited with larger revenue generation. At the same time, the revenue-generating activities generally create costs that must be covered. Through a balance of activity-based and discretionary budgeting, the provost and president retain considerable discretion in funding initiatives at the school, college, or research-unit level independently of current revenue-generating capacity. The system is designed to reserve flexible resources that can be reallocated across units.

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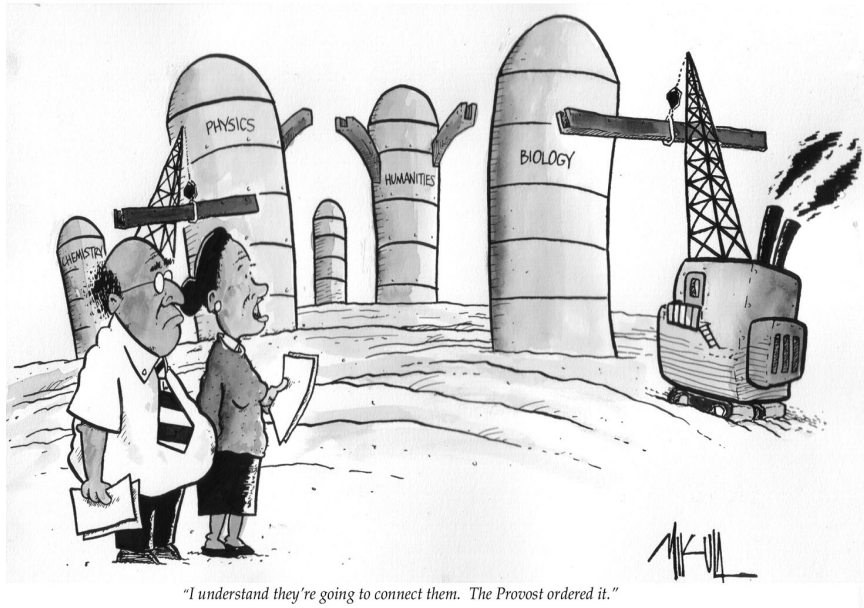
[a]González, C. (2003) The Role of the Graduate School in Interdisciplinary Programs: The University of California, Davis Budget Model. CGS Communicator, Vol. XXXVI, Number 5.

[b]Courant, P. N. and Knepp, M. "Budgeting with the UB Model at the University of Michigan," Office of the Provost, University of Michigan, 2000. *www.umich.edu/~provost/budgeting/ubmodel.html.*

mon" and for new initiatives. Some institutions, including Columbia University, are using resources such as revenues generated from the licensing of intellectual property, to invest in new interdisciplinary research and teaching initiatives (see Box 5-8).

CONCLUSIONS

It is possible for administrators of academic institutions to create supportive environments and policy structures that allow researchers to do their best—including interdisciplinary researchers, who face the special challenges summarized above.[16]



"I understand they're going to connect them. The Provost ordered it."

[16]See Holton, G., Chang, H., and Jurkowitz, E. "How a scientific discovery is made: A case history", *American Scientist*, Vol. 84, July-August 1996, pp. 364-75. The authors write that scientific innovation "depends on a mixture of basic and applied research, on interdisciplinary borrowing, on an unforced pace of work and on personal motivations that lie beyond the reach of the administrator's rule book" (p. 364).

Because research is difficult to manage, there are limits on the institution's ability to effect change; new fundamental knowledge cannot be produced on cue or on schedule. Nonetheless, the committee suggests that an institution can create an environment in which research flourishes by adapting organizational elements to its particular culture. Such an environment might be characterized by flexibility, a natural, unforced pace of work, and policies that promote borrowing and sharing within and between disciplines. As researchers find new collaborators, join new conversations, and enter new disciplinary cultures, they increase their opportunities to generate new understanding.

FINDINGS

In attempting to balance the strengthening of disciplines and the pursuit of interdisciplinary research, education, and training, many institutions are impeded by traditions and policies that govern hiring, promotion, tenure, and resource allocation.

The success of IDR groups depends on institutional commitment and research leadership. Leaders with clear vision and effective communication and team-building skills can catalyze the integration of disciplines.

RECOMMENDATIONS

Academic Institutions' Policies

I-1: Academic institutions should develop new and strengthen existing policies and practices that lower or remove barriers to interdisciplinary research and scholarship, including developing joint programs with industry and government and nongovernment organizations.

For example, institutions can

- Provide more flexibility in promotion and tenure procedures, recognizing that the contributions of a person in IDR may need to be evaluated differently from those of a person in a single-discipline project. Institutions could
  - — Establish interdisciplinary review committees to evaluate faculty who are conducting IDR.
  - — Extend the venue for tenure review of interdisciplinary scholars beyond the department.
  - — Increase recognition of co-principal investigators' research activities during promotion and tenure decisions.

— Develop mechanisms to evaluate the contribution of each member of an IDR team.

- Establish institutional advisory committees of researchers successful in IDR to evaluate new proposals prior to implementation.
- Require regular reviews of IDR centers and institutes and establish sunset provisions, where appropriate, when they are initiated.
- Give high priority to recruitment of appropriate faculty and other researchers whose focus is interdisciplinary; this can be accomplished in part by allocating substantial resources to centrally funded, multidepartmental hiring of faculty and postdoctoral scholars and admission of graduate students.
- Coordinate hiring across departments and centers to maximize collaborative research and teaching possibilities.
- Develop joint IDR programs and internships with industry.
- Allow for the longer startup time required by some IDR programs.
- Gather information about the extent, quality, and importance of IDR in the institution and make the information available to faculty.
- Provide mechanisms to build a community of interdisciplinary scholars across the institution similar to the community that is in a department.

I-2: Beyond the measures suggested in I-1, institutions should experiment with more innovative policies and structures to facilitate IDR, making appropriate use of lessons learned from the performance of IDR in industrial and national laboratories.

For example, institutions can

- Experiment with alternatives to departmental tenure through new modes of employment, retention, and promotion.
- Selectively apply pooled faculty lines and funds available for startup costs for new faculty toward recruitment of faculty with interdisciplinary interests and credentials.
- Experiment with administrative structures that lower administrative and funding walls between departments and other kinds of academic units.
- Create laboratory facilities with reassignable spaces and equipment for people performing IDR.
- Create specific IDR grants and training programs for distinct career stages to assist in learning new disciplines and participating in IDR programs.
- Create mechanisms to fund graduate students and postdoctoral scholars whose research draws on multiple fields and may not be considered central to any one department.

- Develop a process for dealing with intellectual-property allocation that is consistent with encouraging IDR.
- Increase "porosity" across organizational boundaries by
  - — Encouraging joint recruitment and appointment of faculty through resources available centrally.
  - — Creating opportunities for faculty to compete for internal leave for study in a new discipline so as to take courses, training, and additional advanced degrees in their own universities.
  - — Encouraging departments and colleges to work with IDR centers and institutes in hiring faculty with interdisciplinary backgrounds.
  - — Providing fellowships that are portable within the institution.
  - — Allowing courtesy appointments that recognize interactions and collaborations across departments but that do not have the formal split responsibility of a joint appointment.
  - — Placing departments near one another to take advantage of their potential for fruitful interdisciplinary collaborations.

I-3: Institutions should support interdisciplinary education and training for students, postdoctoral scholars, researchers, and faculty by providing such mechanisms as undergraduate research opportunities, faculty team-teaching credit, and IDR management training.

Such education and training could cover interdisciplinary research techniques, interdisciplinary team management skills, methods for teaching nonmajors, etc. For example, institutions can

- Provide more opportunities for undergraduate interdisciplinary research experiences.
- Allow faculty to receive full credit for team teaching in interdisciplinary courses.
- Encourage multiple mentors for students and pairing of appropriate senior interdisciplinary faculty with junior ones interested in IDR.
- Provide opportunities (such as sabbaticals) for students and faculty members to learn the content, languages, and cultures of disciplines other than their own, both within and outside their home institution.
- Support formal programs on the management of IDR programs, including leadership and team-forming activities.

I-4: Institutions should develop equitable and flexible budgetary and cost-sharing policies that support IDR.

For example, institutions can

- Streamline fair and equitable budgeting procedures across depart-

ment or school lines to allocate resources to interdisciplinary units outside the departments or schools.

- Create a campuswide inventory of equipment to enhance sharing and underwrite centralized equipment and instrument facilities for use by IDR projects and by multiple disciplines.
- Credit a percentage of all projects' indirect costs to support the infrastructure of research activities that cross departmental and school boundaries.
- Allocate research space to projects, as well as departments.
- Deploy a substantial fraction of flexible resources—such as seed money, support staff, and space—in support of IDR.

Team Leaders

T-1: To facilitate the work of an IDR team, its leaders should bring together potential research collaborators early in the process and work toward agreement on key issues.

For example, team leaders can

- Catalyze the skillful design of research plans and the integration of knowledge and skills in multiple disciplines rather than "stapling together" similar or overlapping proposals.
- Establish early agreements on research methods, goals and timelines, and regular meetings.

T-2: IDR leaders should seek to ensure that each participant strikes an appropriate balance between leading and following and between contributing to and benefiting from the efforts of the team.

For example, leaders can

- Help the team to decide who will take responsibility for each portion of the research plan.
- Encourage participants to develop appropriate ways to share credit, including authorship credit, for the achievements of the team.
- Acquaint students with literature on integration and collaboration.
- Provide adequate time for mutual learning.