May You Live in Interesting Times: Using Multidisciplinary and Interdisciplinary Programs to Cope with Change in the Life Sciences

JAMES P. COLLINS

A university departmental chair is often asked what might be needed to improve the unit and to move it to the next level. The question can be applied to everything from recruiting faculty members to graduate training to renovations. The question seems to be direct and appropriate because it implies "getting better." But along the way to getting better are tactical questions about how to get there, criteria for assessing change, and deeper strategic questions about where "there" is.

Universities have institutional needs and values, and since World War II, especially in the United States, leading research universities have evolved a shared sense of what these are (Abram et al. 1970, Guston and Keniston 1994, Kerr 1995, Cozzens 1996, Duderstadt 1999, Rosenzweig 1999, Savage 1999). But faculty members, university administrators, and the public may honestly disagree about how much an institution's interests supersede individual and departmental interests. Is the university a public service provider, an economic engine, or a haven for intellectuals trusted to justify society's investment?

A faculty member who asks "What shall I do today?" does not mean "What do you want me to do today?" in the sense that a department chair would literally make daily assignments, but "What do I want to do?" Faculty members face an increasing number of daily choices that make the answer less obvious. Sharpening individual skills, advancing a discipline's scholarship, working with students, administering the department, developing university programs, enhancing economic development, and engaging in public outreach all compete for attention. But what values determine a faculty member's answer? How are these values developed, and how are they passed on to the next generation of scholars?

Faculty members and their departments are frequently the friction point for conflict between individual goals and institutional goals. Tensions between and among individual, departmental, university, public, and national interests are common at the unit level. As leader of the department's faculty but

MULTIDISCIPLINARY AND INTERDISCIPLINARY RESEARCH AND TRAINING PROGRAMS PROVIDE LIFE SCIENCE DEPARTMENTS A WAY TO FOSTER THE INNOVATION NEEDED TO COPE WITH RAPID CHANGE IN BIOLOGY

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also a member of the university’s central administration, the chair is often at the center of these discussions. The chair represents the interests of individual faculty members and a department while assuming responsibilities and a vision that transcends the department. The chair integrates diverse faculty interests, the institution’s mission, and changes in scholarship outside the institution. Managing this process is a challenge, but successful integration of individual and institutional interests can lead to advances in research and training as well as to enhanced investment of university resources—both of which accelerate programmatic development.

Rapid change has typified the biological sciences for nearly 50 years, and the end is not in sight (Appel 2000). As noted in the preface of a 1989 National Research Council report, *Opportunities in Biology,* “The field [of biology] has...changed to the point that no single individual can hope to grasp all of the new activities and opportunities.” The executive summary begins, “The opportunities for exciting advances in the biological sciences...have never been greater than what we are at present. Starting with the establishment of the structure of DNA in 1953...the flow of biological discovery has swelled from a trickle into a torrent.” Biological discoveries are front-page stories in newspapers, and the consequences of these discoveries—gene therapy, cloning, genetically engineered crops, and the loss of biodiversity—are debated on editorial pages. The Age of Biology is now, and universities are at the forefront of the revolution.

Revolutions are exciting, but they strain institutions—hence, the old Chinese curse, “May you live in interesting times.” Biologists and university administrators are in an interesting, challenging time fraught with revolution and change, although neither concept generally springs to mind when we think of universities. Time devoted to rational thought is the hallmark of a scholar; yet, in a world geared toward agile responses to daily challenges, time for thoughtful consideration is an increasingly rare luxury. The urgent is ever the enemy of the reflective.

This article reviews, as a case study, how the biology department at Arizona State University adapted to change as it struggled to find the right balance between individual and institutional goals. During the decade covered here, the biology department tested the thesis that multidisciplinary and interdisciplinary programs can foster, accelerate, and sustain constructive change in academia. We had intellectual and practical reasons for adopting this strategy, which enabled us to make the best use of the diverse talents of departmental personnel. Developing disciplinary strengths was not to be neglected; rather, we chose as a department to encourage multidisciplinary and interdisciplinary thinking as a complement to disciplinary thinking.

There is not unanimity on the meaning of multidisciplinary and interdisciplinary, but Beggs (1999) provided a guide. A discipline is a body of knowledge or branch of learning characterized by an accepted content and learning. Research, problem solving, or training that mingles disciplines but maintains their distinctiveness is multidisciplinary. Practically speaking, investigators from at least two disciplines work together, but do not typically design experiments, analyze results, and publish together; a training grant that supports students in several disciplines is one example. The key point is that cooperation among faculty members need not be any greater than that all agree to support students in laboratory rotations. Teaching, learning, research, or problem solving that integrates several disciplines to create a unified outcome that is sustained and substantial enough to enable a new discipline to develop over time is interdisciplinary. Practically speaking, completing the project requires the joint effort of investigators from two or more disciplines. Consequently, collaborative experiments, analysis, and publication are often the product. Integrating the diverse expertise of the participants is the key to success.

Just over a decade ago we reasoned that biologists had spent some 40 years pursuing a largely reductionist research and training strategy, and that the discipline would soon need integrative thinkers to synthesize the diverse knowledge that was accumulating. We wanted to work with our students in helping to effect that change. Programs drawing on multiple investigators had several practical benefits as well. We could leverage our diverse strengths in the life sciences, thereby accelerating our development as an internationally recognized center for training and research. Collaborative programs also provided access to major new sources of external funding. Finally, by providing many ways for faculty members to participate in research and training activities, multidisciplinary and interdisciplinary programs could, in theory, support change within units and institutions with less discord among colleagues.

**Multidisciplinary and interdisciplinary research and training**

Over the last decade, ASU’s biology department has developed around a model integrating didactic, historical, philosophical, ethical, and subdisciplinary elements. At the model’s center is our department’s mission: to understand life through learning and investigation.

A university must require excellence in teaching (Kennedy 1997, 2001, González 2001). A decade ago the faculty in biology asked, What do we want our students to know when they graduate? Our answer: Not just how to memorize facts. We envisioned learning as the creative process by which new knowledge is discovered. We wanted our students to think like scientists, so we became self-conscious about teaching science as science is practiced. Reports from AAAS (1990) and NSF (1996) guided our reforms, as well as research in biology education by departmental faculty members (Lawson et al. 1990).

ASU could not provide all of the resources necessary to meet our training goals, so we sought external funds. Since 1992 about 30 biology faculty members have served as principal investigators (PIs), often project directors (9 of 12 grants), on nine undergraduate and three graduate training grants (Table 1). These grants have supported laboratory equipment and

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Note: Brackets indicate that a biology department faculty member was a co-PI, but not project director. ACEPT, Arizona Collaborative for Excellence in the Preparation of Teachers; DARPA, Defense Advanced Research Projects Agency; HHMI, Howard Hughes Medical Institute; KDI, Knowledge and Distributed Intelligence; LTER, Long-Term Ecological Research; MARC, Minority Access to Research Careers; NASA, National Aeronautics and Space Administration; NIH, National Institutes of Health; STS, Science and Technology Studies; UBEPI, Undergraduate Biology Enrichment Program.

renovation; faculty workshops to develop new approaches to learning; curriculum development; graduate courses, travel, and fellowships; and an undergraduate research program (Biology Research Experience for Undergraduates, or BREU). Recruiting excellent graduate students remained a priority. Our ability to recruit the best students improved through the use of university funds, sometimes from vacated faculty lines, to increase stipends and provide health insurance.

Research and training require specifying research questions. Successful researchers also ask why one question is superior to another, at times leading us to assess our research and teaching from the perspective of history and philosophy of science. What is the nature of our discipline or subdiscipline? What drives disciplinary change? Our department's interest in research questions spanning multiple biological subdisciplines and multiple organismal models led us in 1998 to redefine ourselves as a biology department, changing our name and focus from zoology. Our conviction that there are many questions in ethics, law, business, and politics that are best analyzed by individuals trained at the interface of the life sciences, humanities, and social sciences led us to create a concentration in biology and society in 1996. We have three historians and philosophers of science in our department, expanding what it means to be a biology department, even a science department, at the start of the 21st century.

Excellence in biology requires specialization to understand leading research questions, sophisticated equipment, and complex methods, but much of today's exciting research requires breadth to draw on several disciplines and subdisciplines. Resolving the specialization versus generalization tension preoccupies many biology departments. No organizational structure can satisfy all of the sometimes contradictory needs of specialization and generalization, but multidisciplinary and interdisciplinary programs give a diverse group of faculty members a common ground on which to meet. Again, ASU could not provide all of the resources to meet our aspirations; therefore, as we had done for our training programs, we sought enhanced external support for research. Since 1993 the biology department's faculty members have served as PIs on 11 interdisciplinary research grants, and as project directors on six (Table 1); over the same period the department secured an average of 53 grants per year.

Multidisciplinary and interdisciplinary programs do not magically foster change. Rather, the best contemporary research and training demand intellectual agility, quick assessment, rapid response to information, and an openness to new ideas from diverse disciplines. Increasingly, research and training programs encourage collaboration, placing a high value on collegiality and cooperation. One way to appreciate the complexity of decisions at the intersection of disciplinary diversity, personalities, and forces internal and external to the university is to consider a specific case. The biology department at ASU affords such a case, and our external funding record is a practical starting point.

Change in the biology department at Arizona State University

Resources for new programs. Our external funding has increased fivefold over the last 15 years (Figure 1). The biology department had about 30 faculty members between 1989 and 1999; half of the department's faculty members in spring 2001 had joined the department since 1990. Many faculty members appointed since 1990 have had an increased
interest in collaborative research and training that matched a heightened willingness to collaborate within the department. About 80% of the department's faculty members, with little variation, were funded externally in each of these 15 years. Therefore, the change in funding level is not attributable to having more faculty members, nor to having a greater percentage of faculty members funded. Instead, it seems to have derived from an interest in collaboration among new and existing faculty members in the department.

One interpretation of the data is that our external funding has increased steadily since 1984. Another interpretation recognizes three funding plateaus between the 1980s and today (Figure 1). According to this latter view, we evolved from a unit with most faculty members holding solely individual investigator awards to one that valued faculty members holding individual investigator awards plus multidisciplinary, and then interdisciplinary, research and training awards (Figure 2). Our recent history (1992–2001) of collaborative training and research grants (Table 1) supports this general model of departmental development. From 1992 the biology department's faculty members led or were co-PIs for 12 interdisciplinary training grants and 11 interdisciplinary research grants. The point is that collaboration before the 1990s consumed only a small amount of the time of a few faculty members; over the last decade, however, one-half of the faculty has committed increasing time to collaborative training and research.

Assessing change. Initiating change in a university academic department can be a daunting task; evaluating the change is equally challenging. More of our graduate students now teach less, spending a greater percentage of their time as research assistants. More of them are publishing papers earlier in their careers, time to graduation is reduced, and we recruit a high percentage of our best graduate applicants. Our undergraduate laboratories have better facilities, space, and personnel support. About 25% of our undergraduates have a research experience before graduation, often with financial support from our BREU program. The annual rate of publication by the faculty is unchanged, and it is not clear why. Perhaps it is because the increased funding within interdisciplinary programs does not translate directly to more publications. Larger awards require more time for administration, including developing and supervising the infrastructure to manage the research. After all, the increased funds support a team that was needed to solve a complex problem; however, solving the problem does not necessarily mean more papers. Publication productivity may take a different form—fewer papers, each with more authors, often in leading journals. For our department, some benchmarks improved while others were unchanged. Ultimately, traditional measures of academic success may have to be reassessed in light of our faculty members' changing commitments.

Departments need measures of productivity other than a tally of papers, but the measures should assess performance by faculty members committed to establishing and maintaining disciplinary as well as interdisciplinary programs. Additional measures we might consider, such as journal quality, journal impact scores, and citation indexes, provide a certain view of an individual's career but have an inherent flaw: Each requires assigning a faculty member's program to one or more classes or categories. Such an assignment may be difficult or impossible for investigators on the leading edge of research that is interdisciplinary. Consequently, creative faculty members willing to explore new collaborations may not be valued and rewarded because their research is not easily classified according to measures that depend on drawing rigid disciplinary borders.

Not everyone must change. Beginning in 1990 the university initiated an effort to improve the quality of ASU's undergraduate experience while accelerating our development as a research university. The biology department's faculty wanted better graduate students and postdoctoral associates, and more time to focus on research. We decided that multidisciplinary and interdisciplinary programs would enable our department to progress on unifying individual and institutional needs. But such programs are not the only means for accomplishing this goal.

The "best" way to make progress on answering scientific questions—whether through individual investigator or group effort, for example, or disciplinary or interdisciplinary focus—varies depending on the question and when it is asked. Today's interdisciplinary research area may be tomorrow's discipline. Similarly, the skills for which we train students vary; for example, do we emphasize the ability to work alone or in groups?

We can think of these differences as competing epistemologies, or ways of knowing, and they give rise to diverse values in faculty members and students; for instance, do I value independence or cooperation in colleagues and students? So, saying "We value research," "We value integrating research and teaching," and "We value interdisciplinary approaches" leaves room for debate. Some faculty members may feel that discl-
Figure 2. General model for development of research and training programs. The pattern illustrates the evolution of a funding profile from faculty members with mainly individual investigator-based awards, to collaborative awards involving a team of investigators, and finally, collaborative awards requiring that teams of investigators be integrated. The ordinate is arbitrary and reflects the proportional increase in a department's external funding, where two is a doubling of a unit's funding. Strategic planning is expected to play a larger role in the success of investigators and units that actively engage in collaborative research as opposed to largely individual investigator-based research.

Choosing a way forward. How does a department decide on a course of action? In the end, faculty members individually and collectively resolve a complex set of competing interests and values. As faculty members we are embedded in layers of disciplinary, institutional, and societal obligations. Choosing a way forward depends on preserving debate and the larger view rather than getting mired in the details of our daily actions. Thus we must appreciate that the question, What shall I do today? has many answers, the best of which hinges on forces that vary over time and settings. Adaptability and personal flexibility will very likely serve one well under many circumstances. Likewise, at the departmental level, individual faculty members less open to change must still support and reward colleagues who are open to new approaches to research and training.

As the biology department at ASU evolved over the last decade, we debated how we should change, the values to guide us, and our limitations. How should we identify areas for growth and change? Should we strengthen disciplinary or interdisciplinary fields? Will faculty members be better off if training and research programs are built around individuals perhaps with little relationship to larger departmental, institutional, and societal forces? How do we develop new areas of strength or rejuvenate old ones? What values should guide our decisions about the kind of funding opportunities we seek—that is, whether for an individual or for multiple investigators; source and level of funding; publication quality; supporting institutional initiatives; quality of training for students? What limits us as individuals, as groups, or as a department: teaching load; type or number of colleagues; poor or inadequate space; poor or inadequate staff; release time for developing complex proposals with many PIs; quality of students; seed funds? And how should the movement of universities and funding agencies toward "big science" projects shape our department's faculty and our research programs?

In the biology department's case, we decided that improving the undergraduate program, which had about 700 majors in 1990 and 1100 in 2001, was the place to start. Intellectually, we wanted to integrate two elements of the modern university commonly seen at odds: quality of the undergraduate program and faculty research. We reasoned that our desire to teach science as it is practiced was best manifest by bringing undergraduates into our research laboratories as young investigators, not just as assistants or technicians. Several things followed and each improved the department's research and training programs. Undergraduates forged closer bonds with faculty members. We renovated lecture rooms and laboratories. The number of research personnel, supply budgets for research laboratories, and number of research assistantships (RAs) for graduate students all increased. Funding for these changes came from several sources: the Howard Hughes Medical Institute (HHMI), National Science Foundation (NSF), and National Institutes of Health (NIH) funded salaries and research supplies for undergraduates; NIH and NSF funded graduate student salaries; HHMI funded laboratory renovations; and ASU's College of Liberal Arts and Sci-
ences and the Office of the Senior Vice President and Provost provided generous matching funds for student stipends, laboratory renovations, and staff. Most important, we committed to a departmental model integrating research and teaching.

**Changing a department’s culture.** As biologists at a research university, we had a history of teaching the process of science, primarily to graduate students and postdoctoral associates. Undergraduates became regular participants in many research groups beginning in 1992. From this foothold, the commitment to teaching science as it is practiced infused undergraduate lectures and laboratories more than it had previously. Teaching the process of discovery is what research universities, unlike community colleges and other institutions of higher education, do best. We have integrated graduate students, postdoctoral associates, and faculty members into a model in which undergraduates understand biology through learning and investigation.

Since 1992 we have used external funds and institutional matching funds to support summer workshops, in which a third of our faculty members have already participated voluntarily, and we have funded faculty members to revise lectures and adapt laboratories supporting what is variously called inquiry-based, student-centered, or active-learning education. In addition, we funded the renovation of five undergraduate laboratories, new construction of a laboratory for cell biology and one for physiology, and revision of 13 core courses and five laboratory instructional guides to make them inquiry based. Today, 30 faculty members in biology, and 99 in 17 departments with life scientists, are available to work with undergraduates to develop independent research projects. We place in research laboratories and fund about 80 undergraduates annually.

Practically speaking, focusing on the undergraduate program was the right decision in 1990: Our undergraduate labs had not been renovated in 15 years or more, equipment was outdated, and undergraduates were rarely involved in research. There was widespread agreement among faculty members that the program needed improvement, which made changing it easier. Our decision was propitious because a decade ago ASU’s new president placed at the top of his agenda the enhancement of the quality of ASU’s undergraduate programs. Departmental goals now matched the institution’s, carrying such ancillary benefits as easier access to matching funds for proposals. Simultaneously, national attention turned to improving the undergraduate experience, especially in research, and we pursued and received funding from new programs at NSF, NIH, and HHML. The conjunction of these four levels of organization—individual, department, university, and national—accelerated the biology department’s programmatic improvement.

The first undergraduate training grants and research grants were multidisciplinary (Table 1). Graduate students received RAs, undergraduates brought stipends and supply money to research labs, participating faculty members received summer salaries, and the university recognized the department’s contribution to its agenda by granting the biology department’s faculty proportionally higher salary increases. As faculty members learned to work together and were rewarded for it, multidisciplinary grants began to change the department’s culture relative to collaboration, laying the groundwork for interdisciplinarity research and graduate training grants and requiring laboratories to integrate activities. These later grants supported institutional initiatives in environmental sciences, astrobiology, and basic biomedicine; individual and departmental benefits were comparable to the multidisciplinary grants. Paying attention to the larger picture helped us align often competing values at several levels of organization, and early successes reinforced our movement in this direction.

Resolving competing values is not new, and appreciating this fact is part of gaining a still larger perspective that embraces the history of academic institutions. Newman (1852) described an ideal university that differed from its antecedents, and Pelikan (1992) updated and applied Newman’s vision to late 20th-century universities. Johns Hopkins University adopted the German model of graduate training late in the 19th century, and American universities have made the 21st century version of that model the envy of the world. Woodrow Wilson imbued Princeton with an isolationist worldview, and Stanford took advantage of the cold war to develop into a major research university (Lowen 1997). We know a lot about what to expect as universities and their components change; likewise, we know a lot about how to manage differences, which present new challenges. In Clark Kerr’s (1995) “multiversity,” the fundamental challenge is holding diverse, independent pieces—starting with elite faculty members—to a common mission. Today’s biology departments face a reduced version of this challenge: What is the discipline’s intellectual center? And how do we hold the intellectual center when knowledge is expanding in ways that extend our understanding of what constitutes “biology” far beyond the discipline’s traditional boundaries?

**Sustaining departmental change**

It is worth taking a moment to reflect a bit more on what the plateaus in the biology department’s funding profile suggest about the development of research and training programs (Figures 1, 2). My hypothesis is that the plateaus reflect periods of learning and evolution that occurred, intellectually and in our infrastructure, at three organizational levels: first on the part of individual faculty members, a little later at the departmental level, and later still for the central administration. The lags at the last two levels are probably typical for most universities and perhaps most institutions. They seem to reflect the time it takes for the larger organization to first recognize changes are occurring and then to find the new resources to sustain the worthwhile novelties, as well as time needed by faculty members to master new material and establish networks with new collaborators.

In the biology department’s case, the hypothesis is that during the last decade many faculty members who valued indi-
individual investigator-based research and training programs came also to value multidisciplinary and then interdisciplinary programs. The change in values was part of what some administrators like to call an evolving departmental culture. The evolution we experienced required most faculty members to agree intellectually that collaboration had value. Then the task became one of learning how to collaborate at levels that exceeded the usual two- or three-PI research project. This same pairing of an intellectual decision and its practical consequences also played out at the departmental and university levels.

At the departmental level, we had to agree as a faculty that colleagues who participated in collaborative projects would be rewarded. Specifically, for senior faculty members collaborative projects would count in decisions like assigning salary increases, research space, or teaching loads; junior faculty members had to demonstrate development of an independent research program, but participation in collaborations would also count positively in tenure and promotion decisions. Faculty members had to learn how to assess contributions in the humanities to evaluate colleagues in the biology and society program. We had to accept that relative effort devoted to research, teaching, and service would differ among faculty members in order to accommodate varying commitments to managing large projects with multiple collaborators. The dean of our College of Liberal Arts and Sciences adopted a policy of allowing chairs to use a flexible model for integrating faculty responsibilities and institutional needs (Krahenbuhl 1998). This, coupled with the regents' post-tenure review policy, made it easier to accommodate the shifting career interests of individual faculty members and respond creatively to matching personnel effort and responsibilities with institutional goals in teaching, research, and service. The department also adopted an annual merit review policy that rewards faculty members for collaborative effort that supports departmental, college, and institutional goals. Ten percent of each faculty member's annual performance review reflects contributions to collaborative research and training. We debated all of these decisions, and it took time.

The changes in the department over the last decade have entailed an evolution of not only our intellectual perspective but also our infrastructure. Our staff has increased in size, and staff members spend more time supporting and extending the talents of faculty working individually and in groups. In the central office we added a facilities manager and an administrative associate, and we reclassified the lead business and personnel positions at two levels higher within the university's organizational scheme. For undergraduate programs we added a manager, two professional advisors, and a position for assessment. We rely on staff members with increasingly sophisticated talents to track budgets, maintain complex equipment, and support our research and teaching laboratories, thus providing faculty members with time to create and sustain programs at the leading edge of our fields.

The dean's policy on workload is one example of how the university learned to accommodate the changing culture in biology and other units. Central administrators and faculty members must work together to create collaborative programs like those shown in Table 1; neither can create such programs without the other. The dean of our college and ASU's provost have policies that reward units responsive to the institution's agenda, and not just an individual responding to her or his own agenda. The premise is that individuals will respond to opportunities consistent with the university's agenda if units and individuals are rewarded. The vice president for research provides generous matching funds for research and training proposals with multiple PIs that reinforce university initiatives. ASU supports faculty members who spend time in Washington, DC, working on national and international policy issues related to research, teaching, and service. A junior faculty member in the biology department served as an American Association for the Advancement of Science (AAAS) fellow in the Office of Science and Technology Policy advising the White House on issues such as global climate change, and a senior faculty member served as science advisor to an Arizona congressman.

But institutions also must find funds for research and training at the highest levels. Learning what it takes to create new programs gives rise to what Christensen (1997) called "the innovator's dilemma," and I would add that sustaining the programs causes one to confront the reality of the infrastructure lag. Starting a program requires a commitment by faculty members; the process is often akin to moving out on a limb. Immediately there is the issue of whether the new program will be supported locally, by central administration, or through external funds. Fundamentally, faculty members are stretching and reshaping resources, especially their time budgets, and the practical question is how, if at all, the university will support change.

Assume for a moment a group reaches a new plateau (Figure 1). At this point there can be talk of institutionalizing a program. As a practical matter, however, institutional support for the infrastructure (personnel and other resources) required for a new program typically lags, often by years, establishment of the new program. Hence, the innovator's dilemma: It is tough to start new programs, and because of the infrastructure lag it may be even tougher, and very frustrating, to secure central administration support as new opportunities compete with other needs for limited resources. Likewise, it takes time for faculty members and administrators to determine which infrastructure needs will accommodate the changes. The kinds of staff and their skills will vary with each new plateau. Advancing toward a new level by whatever measure—number or quality of publications, level of external support, quality of instructional programs—means creating an environment in which a new program can flourish. Once the new level is reached, the dilemma lies in incorporating the activities associated with it into a culture that attained prominence doing something else.

Finally, if we accept the hypothesis that the biology department has indeed experienced a transition through three plateaus, it is worth asking whether these steps, or some-
thing like them, are levels through which a department must invariably proceed. Or is it possible to take faculty members with a history of individual investigator–based programs and teach them to be more collaborative—that is, skip directly to larger, interdisciplinary programs? Where does the leadership originate for any of these changes—with faculty members, the chair, the dean, or other central administrators? And how do context and history shape the opportunities for a department and a university to advance its programs? I suspect the best strategy, and very likely the one most difficult to attain, is a judicious mix of leadership from each level, and this tells us something as well: namely, successful programs will increasingly require a design that integrates diverse levels of organization. There is also a message about the value of stable leadership, as leaders play an important role in helping departments and faculty members anticipate and cope with new infrastructure requirements. Change is hard to sustain with people rotating relatively quickly through administrative appointments. Resolving such issues will help us to understand the forces that generate and sustain institutional development (Christensen 1997, Lowen 1997, Zachary 1997, Graham and Diamond 1997, Atkinson 1999, De Alva 1999, Appel 2000).

**Conclusion**

The main question considered here is how faculty members in a large, Carnegie Research 1 university with multiple constituencies can foster innovation in research and training in response to the rate at which new discoveries are being made in biology. Worldwide interest in biology is leading to an increasing number of discoveries, and institutions have an interest in recruiting more life scientists, and certain kinds of life scientists, in response to this need. Biology has been changing at a quickening pace for 50 years, and more change is inevitable. How should universities cope with this change? What is the optimal department size? How should units be organized?

Answers to such questions often come from integrating traditional biological subdisciplines as well as disciplines that extend beyond biology (Collins et al. 2001). Research and training programs of ASU’s faculty members exemplify this view. We have a new (1996) interdisciplinary undergraduate concentration in biology and society that integrates biology, the humanities, and social sciences. In the last 10 years we have appointed to our faculty two historians, a historian–philosopher, and a mathematician–statistician. Biology was a founding department in 1994 with the English, music, and psychology departments of ASU’s multidisciplinary program for graduate students, Preparing Future Faculty, supported by the Pew Charitable Trusts. And we are among six departments that in 1992 started the interdisciplinary graduate degree program in molecular and cellular biology. While we are an administrative unit called “Biology,” we have expanded the definition, generally in multidisciplinary and interdisciplinary directions, of what it means to be a biology department. We envision ourselves less as a component or an isolated element of an organization than as part of an increasingly complex network extending throughout and outside the university.

The transitions over the last decade have not always been smooth, but several factors aided our evolution: greater collaboration and the inclusion of junior faculty members in multiple-investigator proposals; continued hiring of research-oriented faculty; shortened incubation periods for new hires through strong start-up packages; support for more postdoctoral associates and graduate RAs; differential research, teaching, and service commitments among faculty members; and a supportive, flexible central administration.

One way to manage change to take advantage of diverse views among faculty members is through multidisciplinary and interdisciplinary research and training, as exemplified by ASU’s biology department. Not everyone will be happy, but I believe that interdisciplinary thinking serves to keep faculty members engaged in departmental and university affairs for a longer period of their careers than is typical in institutions with a narrower disciplinary focus.

Regardless of what organizational structure a department uses to support its programs, two key elements for future success will be low barriers between it and other units, and institutional flexibility. Both elements reinforce the department's position as part of a network as opposed to an isolated component. Increasingly, departments will be seen less as the center of conceptual and intellectual activities limited to particular disciplines than as portals to a larger interunit and interinstitutional set of relationships. A department will offer its faculty members as much flexibility as possible, and will increasingly sit at the center of an integrated web of relationships. The challenge will be protecting, strengthening, and expanding that web because of the benefits that faculty members and students will derive from being a part of this larger set of interactions. The best scholarship of the future will draw upon as many sources as the mind can imagine, because those sources are now available on a daily basis through networked computers. Fussing too much about organization, therefore, can be a distraction; the key is to create units that are strong enough to support specialized disciplinary and subdisciplinary research while being flexible and general enough to support the large, integrated research programs that are increasingly common in areas ranging from basic biomedicine to environmental biology. Institutional initiatives, departmental values, and an understanding of external forces will allow these units to shape their futures.

In the 1977 Williams James Lecture at Harvard, Donald Campbell (1988), who studied the forces shaping creativity within the sociology of science, argued that “the seamless web of our collective knowledge can no longer (if it ever could) be achieved by Leonhardos who encompass it all in one mind. Instead, it must be achieved by the overlapping of many narrow specialties” in what he called a “fish-scale model of collective omniscience.” His point was that we all support each other intellectually, and our creativity is embedded in a larger framework of overlapping and supporting collaborators. In this context, multidisciplinary and interdisciplinary
programs become "an escape route from what John Montague has called the partitioned intellect" (Heaney 2000). Sometimes departments work to support—even build—these metaphorical patches of fish scales, but too often departments resist such a model by stressing departmental boundaries and disciplinary interests.

One last point: Imagine yourself at the shore among strong waves. Keeping the same location, or moving where you want to go, means getting on top of each new wave. Trying to stay in place by holding your ground on the ocean floor is usually a poor decision. The post–World War II history of American universities teaches us that some programmatic movement is required, if only to stay in place—trying not to change by clinging to what you think is a solid substrate just results in movement without your control. Complex, strong, and shifting forces are at work in today's research universities. Change presents opportunities, and successful programs use the forces of change to the unit's advantage. Perspective is a key to understanding, surmounting, influencing, and using these forces. Among other things, perspective means that no matter how great we feel the changes around us are, in the grander scheme of things they are likely quite small. Realizing this should make change less intimidating.

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